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ABSTRACT

This document contains 65 papers presented at the International Conference on Physics Education. Included are papers dealing with: (1) physics education in China; (2) the evaluation of physics courses in engineering colleges; (3) climate and weather; (4) the implications of physics education research for the classroom; (5) university physics teaching; (6) teacher training in developing countries; (7) community-based physics education; (8) microcomputer-aided physics teaching; (9) standardized examinations; (10) general physics experiments; (11) the application of video techniques in physics teaching; (12) training graduate students in the field of college physics education; (13) light, lasers, and holograms; (14) the reform of general physics courses; (15) scientific inquiry in computer-assisted laboratory experiments; (16) the physics of daily life; (17) the function of physics history on physics education; (18) the apparatus of the Franck-Hertz experiment; and (19) graduate courses on science teaching. (TW)

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Contents

1. Physics Education in China 1
Shen Keqi and Zhao Kaihua

2. On the Quality Evaluation of Physics Course in Engineering Colleges 12
Hong Jing

3. Climate and Weather-- A Physics Course 15
G. Born

4. Implications of Physics Education Research for the Classroom 16
S. L. de Squza Barros

5. The Creation of Supportive Enviroment for Learning Physics 16
D. Nachtigall

6. Problems and Methods of Evaluation in the Teaching and Learning of Physics 17
B. K. Chapman

7. University Physics Teaching and Physics Education Research 23
Yun ying and Tang Fayu

8. Teacher Training in Developing Contexts 29
J. Barojas

9. An Instructional Strategy using Microcomputers for the Teaching of Mechanics 29
B. Bonera, L. Borghi

10. Physical Insight in Classroom Lectures 30
Liang Kumia

11. Community- Based Physics Education 33
Vivien M. Talisayon

12. Self-study Lab--A Trial to Improve the Links in Our Physics Education 34
Yang Zhichang

13. Latent Abilities Needed for Physicists 40
Tsukasa Kuroda

14. A Tentative Study of the Improvement on the Education of the Fundamental Physics in Polytechnic Institutes of China 45
Gou Yongjiang

15. Microcomputer Aided Audio-Visual Teaching System 57
Su Gang

16. Application of Microcomputer in Electrical Experiments 71
Zhu Shigia

17. A Graduate Program in Scientific Instrumentation 79
V. Elings

18. A Diode Star Altas-- a Method of Pointing at Stars 85
Lennart Samuelsson

19. A Radioactive Source Produced in the Classroom 86
Lennart Samuelsson

20. Practice in Teaching Reform of Physics Experiment in Engineering Course 87
Li Shoulin

21. Implication of Research and New Technologies for Teacher Education and Professional Development 91
A. B. Arons

22. An Instructional Strategy Using Microcomputers for the Teaching of Mechanics 118
L. Borghi et al.

23. On the role of Demonstration Experiments in Middle School Physics Teaching 123
Zhang Jingquan

24. Teaching Physics in Developing Countries and the Role of Language 137
R. Kamel Waseef

25. Using Microcomputer-based Laboratories to Teach Physical Intuition 142
R. K. Thornton

26. The Principle of "Color Analysis and Mixing Apparatus" 143
Rang Qinglan et al.

27. Teaching Electronics through Video 149
M. R. Bhiday

28. The Discussion of Physical Thinking and Cultivation of Intelligence and Ability 150
Li Tianzeng

29. The Exploration of Teaching Law of Classical Physical Optics--the Practice of Teaching Innovation of Engineering Physics Optics 156
Shu Suzhen

30. Tutorial Teaching 161
Anthony W. Key

31. How to Cultivate the Faculty of Thinking of Undergraduates in Teaching Basic Physics 162
Luo Weiyin

32. An Approach to the Evaluation on the Teaching Quality of the Lectures on University Physics of Higher Engineering Educational Institution 166
Zhou Shengfang

33. Establishment of the Criteria for the Standardized Sample Examination Paper of Fundamental Mechanics 177
Li Zhengling

34. Discuss the Teaching in General Physical Experiments 182
ang Shuwu

35. A Tentative Study of the Unity between Teaching by Experiments and Cultivating Abilities in Physics Course 185
Wei Yanhua

36. Developing the Research Work On Lab Teaching Raising the Teaching Level 193
Mao Shuqi

37. An Attempt on Student's Experiment-- Making of Thin Film by Vacuum Evporation and Measuring Thickness of the Film 195
S. Okada

38. The Application of TV Video in Physics Teaching 200
Sun Zhiming et al.

39. Teaching Material on Physics 211
Li Chaoying

40. Preliminary Discussion on the Function of Video Recording in Physics Teaching 213
Wu Junmo

41, The Mechanical Universe: Viewing Physics through the Window of Television 218
K.S. Ozawa

42. The Mechanics Universe: New Audiovisual Resources in Physics Education 219
K. S. Ozawa

43. Basic Physics for Biology Students at the University of Sao Paulo 219
E. Okuno et al.

44. Some Considerations in the Planning of the Graduates for Master of Physics Pedagogy of Our University 232
Su Gang

45. On the Training of Graduate Students in the Field of College Physics Education 238
Liang Huanan

46. Light, Lasers and Holograms in Physics Education 243
Simon George

47. Multifunction Apparatus for Franck-Hertz Experiment 259
Yang Mingzhen

48. Optical Pumping Echo 266
Huany Feihu

49. Reform the General Physics Course to Strengthen the parts of Modern Physics 272
Cao shu

50. An Example of the basic Education of Physics for Engineers 276
A. Tsugawa

51. Develop the Role of Teaching Aids by Using Demonstration, Practicum and Audio-visual Programs in Optics Teaching 276
Wang Bingchao

52. Scientific Method of Inquiry Physics Laboratory Using Computer as an Aid 277
Kalpana K. Joshi and S.P. College

53. Physics of Daily Life at High School 277
Y. Hosoume, L.C. Menezes and J.Zanetic

54. A Ripple Tank Demonstration of the Conditions for Interference of Waves 278
Yu, Hao et al.

55. Innovations in 5-4-3 School System— the Experiments of Junior Physics Teaching 283
Zheng Jun, Yan Jinduo

56. Knowledge and Experience on Teachung Selected Papers on the Further Reading of General Physics 290
——Exporations of Rational Knowledge and Ability
Ying Xixiong, Xu Zhichun

57. Guided-wave Light and Its Challenge to Optics 298
Fang Junxin

58. The Functions of Physics History on the Teaching of Physics 305
Zhuang Chongguang

59. Developing the Students' Intollegence is the Most Important Task of the Experimental Course of Elementary Physics 311
Dong Baochang, Ye Shangzhuan

60. Remarks on Two-dimensional Teaching and Multidimensional Examination 316
Yang Zhongchao

61. Remarks on the Research of Experimental Apparatus from the Evolution of the Franck-Hertz Experiment 323
Li Shicheng

62. The Measurement and Evaluation of Physics Teaching Quality in High School 331
Bai Binghan

63. The Impact of Acoustics to Physics Education and Research 338
Wei Rengjue

64. Microcomputer Simulations of a Two-dimensional Ideal Gas: Two models for the Evolution of Speed Distribution 52
R.M. Sperandeo-Mineo and Madonia

65. A Graduate Course on Science Teaching 222
Jesuina L.A. Pacca and Norberto C. Ferreira

6

PHYSICS EDUCATION IN CHINA

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China had a long history and a civilization of long standing. The Chinese people had made important contributions to the development of civilization, science and technology of mankind in the past centuries. There were descriptions and summary of physical phenomena in works of scholars i the period early as 8 century B.C. through 3 century B.C.. A distinguished example was "Mou-Jing" written by Mou Zi* school which comprises studies of logic, mathematics and physical phenomena. The archaeological finds, such as metallic spherical mirrors and musical bell system showed us not only the exquisite workmanship but also the comformity with scientific pri ciples. We can draw conclusion from these facts that the makers caught the empirical rule concerned at that time. Afterwards, the Chinese people had achieved prominent successes in scientific and technological fields, among them the typographic printing and gun powder are wellknown examples. Chinese education has a long history as well. But it is doubtless that the Chinese education, science and technology lay behind the world in the past three hundred years. Systematic modern scientific education just started at the beginning of this century in China. In this paper, I would like to give you a brief introduction of the history and present situation of physics education in China, mainly that of physics major students, as wel as projection of the trends of development. I hope that this will be beneficial to the mutual understanding, exchange and cooperation between our foreign colleagues and us.

I. Physics education in China before 1949

The earliest comprehensive university in China is the capital Grand School which was established in 1898 through the decree of Emperor Guangxu. After overthrown of the Qing Dynasty, its name was changed to Peking University in 1912. There were three divisions, mathematics, physics and chemistry in the natural science school in this university. Peking University started admission of physics program undergraduates in 1913, the prerequisite for admission was finishing the three-year preparatory cours in the university. The length of schooling of physics program was three years. According to the "University Decree" promulgated by the Ministry o Education in October 1912, Bachelor degree will be conferred to the gradu In 1919 the name of "physics division" was changed to physics department. It was the first physics department in China, and the length of schooling became 2 years for preparatory course and 4 years for undergraduate course. Since then physics departments and laboratories were set up in other Chinese universities successively. The curriculum is essentially the same as that in United States.

Before 1913, many colleges and universities offered courses on physic but no physics program. There were foreign teachers in physics. The colle entrance examination subjects comprised physics, e.g. the examination subjects for entering preparatory course of Peking University in 1904 were Chinese, Chinese history and geography, World history and geography, Lang uage translation, Mathematics, Algebra and Plane Geometry, Physics and Inorganic Chemistry.

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* An ancient Chinese scholar, 478 B.C.-392 B.C.

The development of physics education in China were speeded up in 1930's and interrupted by the war. In 1949 there were approximately two thousands students in 35 departments of physics, 12 departments of mathematics and physics, 5 departments of physics and chemistry in different universities, among them about 2/3 being public and 1/3 private. During the war of resistance againt Japan universities in coastal provinces moved to the west, e.g. Tsinghua University and Peking University in Beijing, and Nankai University in Tianjing moved to Kunming in Yunnan Province and united to be National Southwestern Associated University, the Central University in Nanjing, Zhejiang University in Hangzhou and Beijing Normal University in Beijing moved to Sichuan, Guizhou and Shaanxi provinces respectively. In spite of the extremely hard conditions, eminent graduates were cultivated through the consistent, arduous efforts of the faculty, e.g. Nobel prize laureate, Dr. C.N. Yang got Bachelor degree and Master degree in physics in Southwestern Associated University and the other Nobel prize laureate Dr. T.D. Lee was transfer student from Zhejiang University to Southwestern Associated University. The curriculum in this university is given in the following as an example at that time.

Curriculum of physics program in Southwestern Associated University during 1938-1946

A. Commen requirement for science students

Freshman Chinese (1yr, 6credits), Freshman English (1yr, 6), Chinese History (1yr,6), Introduction to Economics (1yr, 6)*, Second Foreign Language (1yr, 6)**, Physical Education (4yrs, no credit).

B. Requirement for physics major students

General Physics (1yr, 8 credits), General Physics Lab (1yr, 3), Calculus (1yr, 8), Differential Equations (1 term, 3), Mechanics (1yr, 6), Electricity and magnetism (1yr, 6), Electricity Lab (1yr, 3), Heat (1yr, 6), Optics (1yr, 6), Optics Lab (1yr, 3), Kinetic Theory of Gases (1 term, 3), Principles of Radio (1yr, 6), Radio Lab (1yr, 3), Modern Physics (1yr, 6), Modern Physics Lab (1yr, 3), General Chemistry (1yr, 8), General Chemistry Lab (1yr, 3).

C. Electives

Any liberal arts or science course may be chosen. The following courses are examples of the elective physics courses offered: Applied Electricity, Properties of Matter, Fluid Mechanics, General Astronomy, Astrophysics, Electromagnetic Theory of Light, Statistical Mechanics, Quantum Mechanics, Spectroscopy, etc.

D. 132 credits were required for graduation and the graduates got B.Sc.

As for postgraduate study, some universities (e.g. Tsinghua University) enrolled Master degree seeking graduate students since 1930's. According to the stipulation of the 'Academic Degree Conferring Act' announced by the government in 1935, the university is authorized to confer Bachelor and Master degrees, and only The Ministry of Education can confer Doctor degree. Due to the influence of war, only two hundred master degrees in all disciplines were conferred before 1949 and no Doctor degree being conferred.

II. Physics Education in China in the period 1949-1966

In this period, generally speaking, the physics education in China had developed both in quantity and quality and met the needs of development of economic construction, culture and education. Its major features are as follows:

1. The reorganization of universities and colleges and the related changes in physics program.

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*It is required to take any one of the following courses: Economics, Political Science and Sociology.

**Most students take German for two years, the requirement is only one year.

The universities and colleges in China underwent a nation-wide reorganization from 1949 through 1953. The main points are: (1) all private schools became public; (2) all schools were modeled in 5 categories: Comprehensive universities, cultivating qualified personnels in humanities, social sciences and natural sciences; normal universities and teachers colleges, cultivating secondary school teachers; polytechnical institutes, cultivating engineers in various fields; specialized colleges, cultivating personnels in a special field or industrial department, e.g. medical college, agricultural college, college of finance and money, aeronautical engineering institute, geological institute, college of textile engineering, etc. ; institutes (junior colleges) for specialized training with 2-3 years program. (3) small schools of the same type were merged into one larger school.

As a result of this reorganization, the number of schools was reduced from 205 in 1949 to 181 in 1953, the size of each school became bigger, the total enrolment increased quite a lot(from 116,504 in 1949 to 212,181 in 1953) and the academic level of teaching were raised due to the rational deployment of the faculty member as well as the rational use of the equipments. The engineering, agricultural and medical colleges were put under the direct leadership of corresponding ministries, so it resulted in the integration of education with the manpower need in these fields. But this reorganization led to some new problems for physics education. Since physics departments existed in comprehensive universities and normal colleges and at the same time engineering departments existed only in engineering colleges, physics as a basic science is divorced from the engineering sciences. Such a situation is harmful to the development of physics as well as the teaching and research of other applied sciences. Being aware of this problem, the comprehensive universities established applied physics programs, or departments as well as researches at the end of 1950's. At the same time, the engineering colleges set up applied physics programs and departments.

2. A big increase in enrolment of students. Fig.1 shows the increasing of the national total enrolment from 1949 through 1965. Fig.2 shows the variation of new physics students admitted for each year in the same period. From Fig.2 we can see two prominent peaks at 1958 and 1960 accompanied by two dispersions. This reflects something wrong in decision making in the development of educational undertaking in China. The national development really needs faster development of education, but if the rate of expansion is too high, it will be divorced from objective situation and thus lead to an inevitable passive contraction. In the long run, the development may be faster if we adopt a proper steady speed instead of such abrupt rise and decline. Moreover, the conditions of teachers and equipments cannot keep pace with such a high speed, thus decline of quality of education will occur and

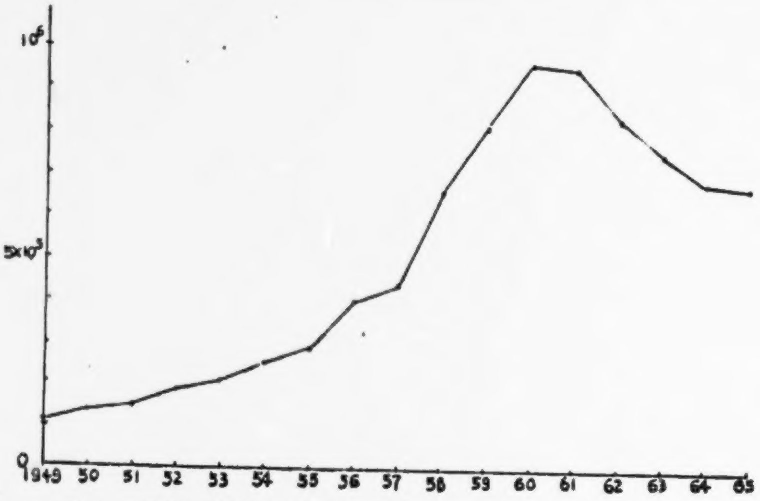

FIG.1 NATIONAL TOTAL ENROLMENT IN INSTITUTIONS OF HIGHER EDUCATION BY YEARS

result in deeper effects.

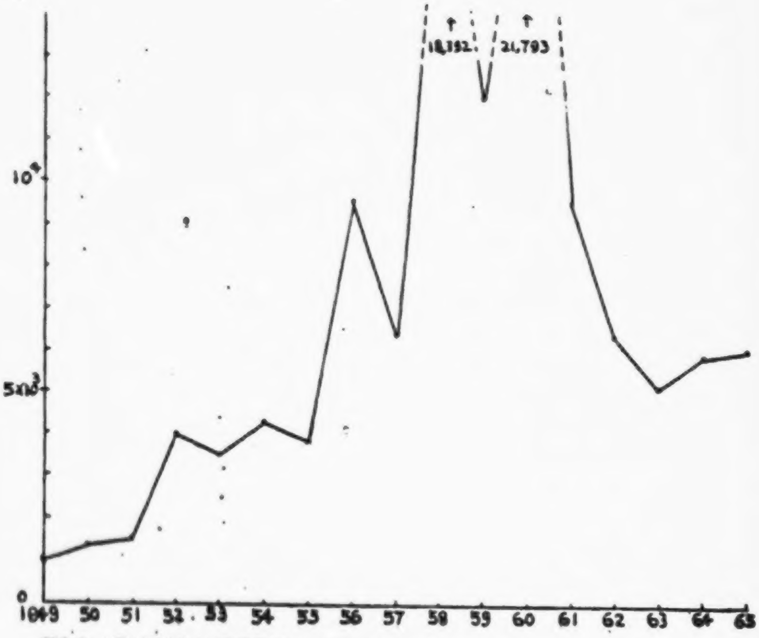

FIG.2 NEW PHYSICS STUDENTS ADMITTED TO ALL INSTITUTIONS OF HIGHER EDUCATION BY YEARS

The another characteristics of the development in this period is the high rate of expansion of teachers colleges. Since China has a big population and the education in China has been seriously underdeveloped, we did need speed up the teacher training education in order to raise the cultural level of the whole nation. For this purpose, many comprehensive universities were converted into teachers colleges around 1952 and new provincial normal colleges were set up from then on. To meet the urgent needs for secondary school teachers, short cycle (2,3 years, mostly 2 years) courses were given in the colleges. For this purpose junior teachers colleges were set up successively. The short cycle students occupied a large portion of the physics students in teachers colleges. Fig.3 shows the variation of new physics students, including both 4-year program and short cycle course students,admitted to teachers universities and colleges. There are also two peaks, where the short cycle course students contributed a significan portion, e.g. 7822 in 12827 (first peak) and 4556 in 11495 (second peak). Fig.4 shows the variation of the total enrolment in middle schools from which we can comprehend why the people wish to have a high rate of expansion of teacher training education.

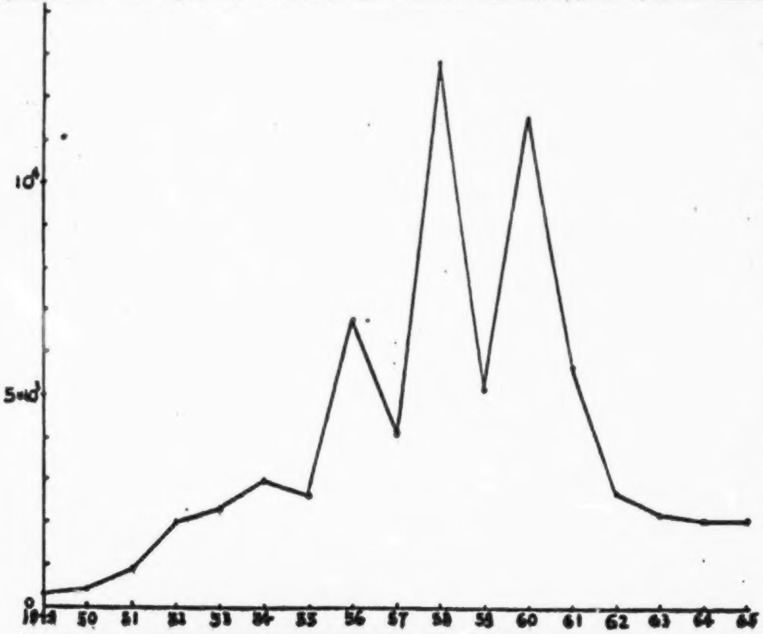

FIG.3 NEW PHYSICS STUDENTS (REGULAR & SHORT CYCLE) ADMITTED TO TEACHERS UNIVERSITIES & COLLEGES BY YEARS

Fig.5 shows the variation of the total new physics students admitted to comprehensive universities. The dip at 1951-1952 was caused by converting several comprehensive universities to teachers colleges as mentioned above. Actually, the new physics students admitted each year was increasing steadily.

It can be seen from these figures that the higher education in China reached a steadily developing stage in 1963-1965, which conformed to both demand and objective possibility. Unfortunately, the so called culturalrevolution started in 1966 and resulted in disastrous outcome for education. The physics education were interrupted or seriously distorted from 1966 through 1977.

3. "Speciality" and curriculum of the physics speciality

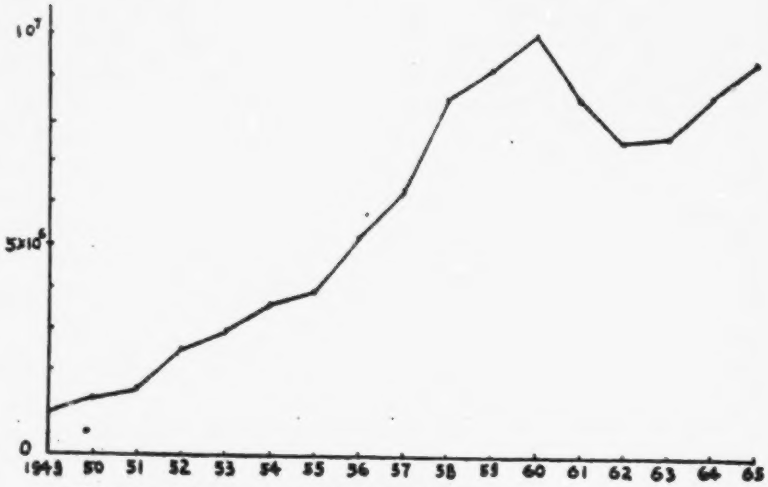

FIG.4 TOTAL ENROLMENT IN MIDDLE SCHOOLS BY YEARS

The educational system in China underwent a drastic change in 1952. The new educational system adopted was essentially that in Soviet Union. The students are cultivated according to "speciality" which is similar to major in U.S. with some differences, e.g. there are no minor and the required courses are restricted to limited fields as shown in the following. For each speciality there is a rigorous curriculum. In comprehensive universities there was only one speciality, ie. the physics speciality in the field of physics at the outset. Several years later, specialities of subfields of physics were set up, e.g. nuclear physics, solid state physics, optics, electronics, semiconductor physics, theoretical physics, etc.

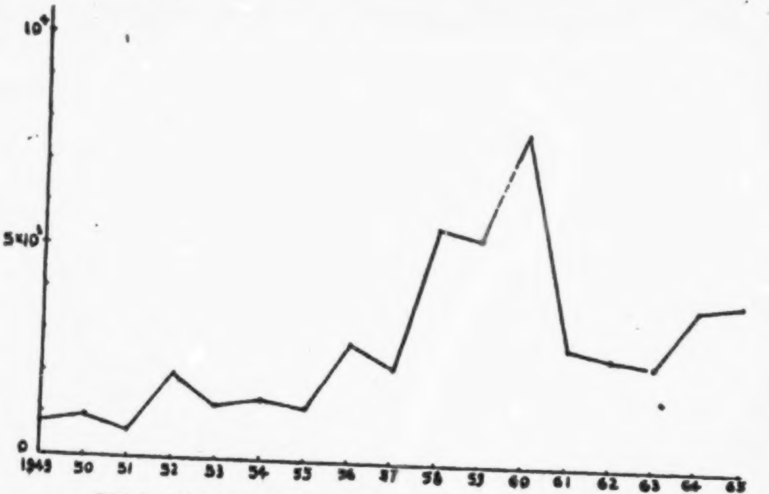

FIG.5 NEW PHYSICS STUDENTS ADMITTED TO COMPREHENSIVE UNIVERSITIES BY YEARS

The curriculum of physics speciality is essentially the same as that in Soviet Union. Besides the common requirement on humanities and social sciences, the natural science courses, essentially mathematics and physics, may be categoried into three parts: (A) Basic courses: Higher mathematics (2yrs), General Chemistry and Lab (½yr), General physics (2.5 yrs), General physics Lab (2 yrs). (B) Basic courses at higher level: Method of Mathematical Physics (1 yr), Theoretical Mechanics (1 yr), Thermodynamics and statistical Physics (1 yr), Electrodynamics (1yr), Quantum Mechanics (1 yr), Electronics (½ yr), Modern Physics Lab (1 yr), Solid State Physics(½ yr).

(C) Training in a special subfield of physics. The senior students in physics speciality were divided into several specialized groups according to the subfields of physics. For each specialized group, courses in this subfield were offered and thesis work is required. Every university set up the specialities according to its own condition, thus it may be quite different in different universities. In the normal universities and colleges, there were no specialized groups but courses related to education, such as Principles of Education, Psychology, Physics Teaching Methods, as well as Teaching Practice.

The curriculum changed frequently during this period. At the outset, the length of schooling was 4 years, with high class-hours per week and heavy burden to students. For the sake of releasing the heavy burden of students and raising the quality of learning, the length of schooling of physics speciality in Peking University was changed to 5 years for freshman in 1953. Inthe 5 years curriculum, about 1 year is devoted to special training, and nearly 4 years are devoted to basic courses in order to enable the graduates to have a solid basis on mathematics and physics. To allocate 1 year to special training is based on such considerations: The scientific and technological basis in China lags behind the world level, the scientific and technological works in industrial departments are just in the initial stage, while the scientific and technological staff is very weak. Therefore the industrial departments demand physics graduates with special training in a subfield of physics and the ability to do scientific work independently. For example, the semiconductor research institutes or factories need people being acquainted with semiconductor physics, semiconductor materials and devices, and being able to do practical work. Thus comparatively systematic course studies and a scientific training for several months are necessary. Nearly all physics departments in comprehensive universities peolonged their length of schooling to 5 years in 1953. The Peking University went further afterwards in this point. The length of schooling was prolonged to 6 years with two years devoted to the training in a special subfield, including a half-year thesis work. Many courses reached graduate course level. Take the specialized group on theoretical physics as an example, the courses required were as follows, Special Functions, Group Theory, Advanced Quantum Mechanics, Quantum Statistical Physics, Theory of Solids, Theory of Nucleus, Particle Theory, General Relativity, and Computational Methods.

The main shortcomings in this curriculum were, (1) No elective course or very few electives, (2) the burden of students was still so heavy that the students were forced to be in a passive position and thus their initiatives were suppressed. This curriculum was greatly revised in 1964, most theoretical physics courses became term courses, electronics was strengthened, and class hours per week was reduced. Taking into account the changed situation, the length of schooling of physics department of Peking University returned to 5 years.

4. Cultivation of Graduate Students

Degree system in China was abolished in 1949. The student got certificates after completing undergraduate program or graduate program. However there was a big increase in the number of graduate students during this period. The statistics reported that the total amount of graduate students admitted in all fields from 1949 through 1965 is 23,393, among them 16,397 being graduated before 1966. In fields of natural sciences these figures are 2,773 and 1,398 respectively, among them around one quarter was in the field of physics. Fig. 6 shows the variation of enrolment of postgraduates in natural sciences from 1949 through 1965. The depression at 1952 was due to the reorganization of institutions of higher education.

The second depression around 1959 reflects the wrong decision making on the development of graduate education at that time. The higher education in China turned out to be regular again in 1961, thus the number of postgraduates increased after 1962.

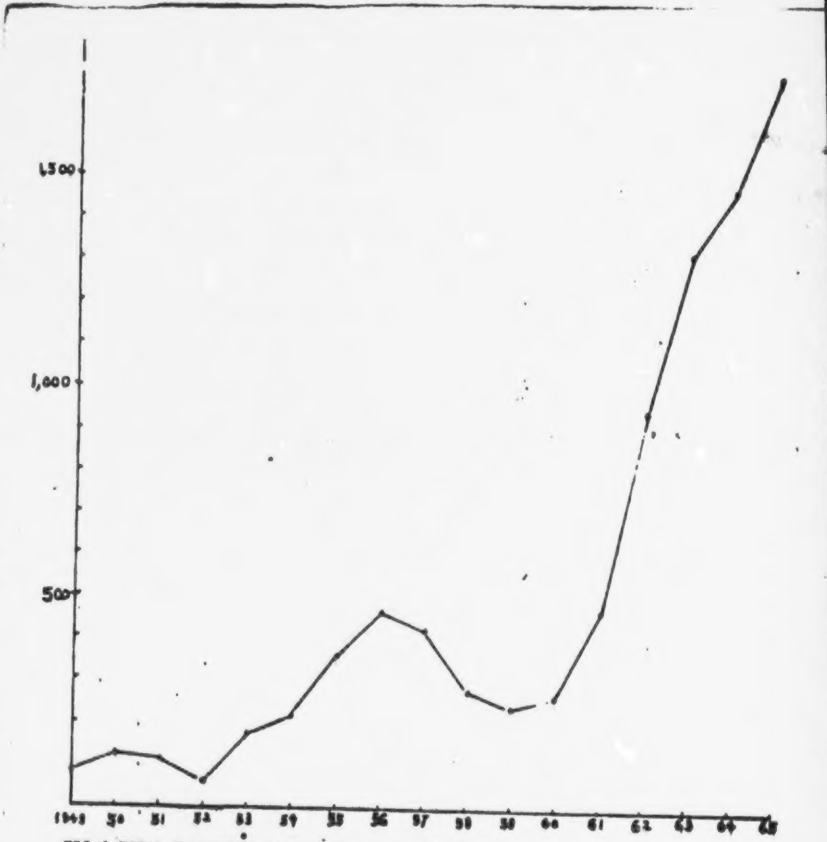

FIG.6 TOTAL ENROLMENT OF POSTGRADUATE STUDENTS IN NATURAL SCIENCES BY YEARS

III. The current situation of Chinese physics education

The education in China was relieved from the chaos and confusions caused by cultural revolution in 1977 and entered into the regular orbit progressively and rapidly. In the past nine years, on the basis of summarizing the experiences and drawing lesson from the past, the education in China has development both in quantity and in quality. The major features of the present physics education in China are as follows.

1. Length of Schooling. It is 4 years for undergraduate study except few universities.

2. Degree System. According to 'The Regulation on Academic Degree of PRC' which come into force from Jan.1,1981, there are three ranks of academic degree: Bachelor, Master and Doctor. The state council's Academic Degree Committee is in charge of directing academic degree conferring affairs and approving doctor degree, master degree conferring units as well as doctor candidate supervisors. The length of schooling for master program is 2-3 uears and 2-3 years more for doctor degree.

3. Curriculum. There are more flexibilities in the curriculum than before, such as: (1) The total credits of required courses only amount to 70-80% of the total credits required for graduation instead of nearly 100% in the past; (2) the universities are authorized to formulate curriculum instead of executing the unified curriculum. The curricula of different universities are different, but essentially the same. The basic courses are retained in the curriculum, but the contents of theoretical physics are reduced generally. The credit system is adopted. The students are no longer divided into specialized groups and the courses in subfields are elective instead of being required, the time for thesis work is reduced. All these changes are suited to the shortening of schooling years and the fact that the demand for training in a subfield of physics in undergraduate program is weakened by the expanded enrolment of postgraduates and the strengthened technical staff in industrial departments.

4. Speciality and Enrolment. More specialities of subfields of physics

and applied physics were set up, but the broader physics speciality still contribute the largest portion of enrolment. The specialities on applied physics which belong to electrical engineering or material science departments in U.S. are put into physics category in statistics in China.

Table 1 shows the establishment of specialities and enrolment of students by specialities in the physics category in 1985-1986.

Table 1 Statistics of Speciality and Enrolment of Physics Undergraduate in 1985-1986

Category of the colleges	Speciality	No. of specialities in whole country	Total undergraduate enrolment	New students admitted in Fall, 1985
Comprehensive Universities	Physics	28	7,547	1,692
	Applied Physics	6	191	104
	Theoretical Phys.	4	232	99
	Radio Phys.	8	940	271
	Radio Electronics	16	3,081	809
	Wave Propagation and Antenna	1	100	40
	Electronics	6	784	254
	Microelectronics	4	353	145
	Semiconductor Phys.	10	855	260
	Laser Physics	1	75	15
	Optics	6	398	145
	Technical Optics	1	284	69
	Opto-electronics	2	123	40
	Metal Physics	3	272	56
	Solid State Phys.	2	218	85
	Acoustics	2	163	42
	Modern Physics	1	53	28
	Nuclear Physics	6	652	163
	Space Physics	2	62	10
	Sum		16,383	4,327
Normal Univ. and colleges	Physics	81	19,827	5,273
	Radio Phys.	8	595	176
	Sum		20,422	5,449
Polytech. Institutes and Engineering Colleges	Physics	7	1,148	382
	Applied Phys.	24	2,175	767
	Semicond. Phys.	1	88	31
	Laser Phys.	1	119	30
	Optics	1	116	38
	Opto-electronics	1	31	31
	Metal Phys.	2	254	65
	Solid State Phys.	2	59	59
	Modern Phys.	2	457	70
	Accelerator Phys.	1	86	0
	Nuclear Electronics	2	156	40
	Technical Phys.	1	161	40
	Sum		4,850	1,553
Total			41,655	11,329

5. Short Cycle Physics Course Students. As mentioned above, there is a big number of short cycle course physics students in the physics departments of junior teachers colleges and the short programs offered by universities and 4-year colleges.

Table 2 Enrolment of short cycle course physics students

Category of the school	Number of schools having enrolment	Total enrolment	New students admitted in Fall 1985
Junior Teachers Colleges	171	21,732	9,072
Normal Univ. and colleges	46	3,121	1,416
Polytechnical Institutes and Engineering Colleges	7	290	159
Comprehensive Universities	11	724	340
Total	245	25,867	10,987

From Table 1 and Table 2 we may get some idea about the scope of short cycle course for teacher training in China. In 1985 the total new students (including both short cycle and regular programs) admitted to normal universities , colleges and junior teachers colleges amounted to 15,937. This results from the demand of a large number of secondary school teachers and students in China. The total enrolment of secondary students in 1985 amounted to 50.93 million. We will return to this point in the following.

6. Increase of Graduate Students. The enrolment of graduate students increases year by year since its restoration in 1978. In the field of physics now there are 63 doctor-degree granting units (each subfield of physics is counted as one unit), 171 master-degree granting units and 129 doctor candidate supervisors. They are approved by the State Council's Academic Degree Committee. In 1985, the new master program students in physics was 1,329 and the corresponding total enrolment was 2,625. In comparison with those figures in 1984-85, 694 and 1884, the increase are 91.5% and 39.3% respectively, that is a high rate of expansion. The length of schooling of master program is 2-3 years. It is required to complete both course work and thesis work for getting master degree. For doctor program students in physics, the figures are much smaller, only 31 in 1983 and 54 in 1984. A master degree is a prerequisite for the doctorate in general, but few excellent students may upgrade directly to doctor programs after one or two years graduate study. The length of schooling of doctor program is 2-3 years, essentially devoted thesis work.

IV. The Trends of Development of Physics Education in China

1. It is projected that the demand for graduates from normal universities and colleges will continue to be increasing due to the national development of secondary school education.

Physics is a required course in secondary school. In the current teaching program, the class hour for physics in junior middle school is 164, and for high school there are two alternatives--268 or 336 hours to be chosen by the school according to their own conditions. The teachers in secondary school are drawed mainly from normal universities and colleges in Chinese educational system. Now there is a serious shortage of teachers, especially qualified teachers in secondary schools. In addition, further increase in the number of students is projected, it will make the problem more serious. Therefore the expansion of normal universities and colleges is inevitable. In the near future, the short cycle course students will continue to occupy an important place in order to meet the urgent needs. From the numerical figures in Table 3 we can conceive the arduous task we are facing.

Table 3. Enrolment of Secondary School Students in 1985

	Total enrolment (millions)	New students admitted (millions)	Graduates (millions)
Junior middle school	40.1	13.67	2.72
High school and secondary school	10.82	4.23	10.07
Sum	50.92	17.90	12.79

The birth rate is reduced through family planning, however, now there are still 18 millions each year admitted to the primary school. The Act of Compulsory Education stipulates that every citizen should take 9 years of education compulsively. Taking into account of the different degrees of development in various regions and the existing economic and cultural condition, it is required to realize the 9 years compulsory education in different periods for different regions. It is projected that in the next 5 years 75% primary school graduates will be admitted to junior secondary school, i.e. 13.5 millions each year, and 40% junior secondary school graduates will be admitted to high school or specialized secondary school, i.e. 5.4 millions each year.

2. To raise the quality of physics teachers is a long term serious task in physics education.

A qualified physcis teacher in secondary school should complete the 4-year physics program at least. Now most physics teachers didn't fulfill this requirment, since many teachers only graduated from 2-year short cycle course or even shorter training course after graduation from high school. To raise their quality through systematic continuing education is the key to the improvement of quality of secondary school education. The authorities of educational department and institutions of higher education should pay a great deal of attention to it and achieve the aim in a planned way.

3. Employment of physics graduates from comprehensive university and institute of technology.

Physics program is the discipline which enrolls more students than the other disciplines and has more talent applicants in the entrance examination in China. The physics circle had a discussion about whether the physics students are excessive or not. The mutual understanding attained is as follows. It seems to be excessive in the assignment of position for physics graduates. In fact, it results from the fact that both the students themselves and the community misunderstand the roles physics graduates should play. Their conception "physics graduate should do physics teaching and basic research or pursue physics graduate program exclusively" has blocked the way to more positions in broader fields for physics graduates, e.g. to pursue postgraduate studies in other disciplines, to do applied research and development work in industrial and agricultural institutions. The comparatively qualified mathematics and physics basis of the graduates can make them suited for working in various economic and cultural departments. For this purpose, the curricula should not be overspecialized and the physics circle should make effort to enable the administrators of industrial circle to realize the importance of physics personnel in the reformation of the industry for being competent in the market.

4. It is projected that the postgraduate student will continue to increase steadily. In this year the master degree granting units and doctor degree granting units in the field of physics is expected to increase 50% and the professors authorized to be doctor candidate supervisor will be doubled, as recommended by the appraisal group of the State Council's Academic Degree Committee. The development of higher education and the R and D in the whole country has continually enlarged the demands for master and doctor production. In the meanwhile the capacity for cultivating graduate students has been greatly strengthened during recent years. There are compatible conditions in faculty and facilities for enlarging the enrolment of graduate students. In the past years, the main resources for teaching staff in universities and colleges are graduates which just had completed undergraduate program instead of graduates from graduate schools. Strictly speaking, they are not qualified enough to undertake their duties. Now as a result of the notable increase of enrolment of graduate students, many advanced universities decided to recruit teaching staffs only from those with master or doctor degrees, in order to maintain and raise the intellectual quality of the entire institution.

5. The main trends of reformation of teaching is to increase flexibility and to strengthen the fortering of the ability in all aspects.

In the national conferencesor seminars on physics education most participants reach unanimity at the following views: the major shortcomings of the present physics teaching are, excessive teaching contents, forced feeding method of teaching instead of elicitation method, taking a one-sided approach to the evaluation of the quality of education with the amount of knowledges as the unique criterion instead of development of student's intelligence, and insufficient attention paid to fostering the initiative and independent study ability of the students. As a result of these factors, the students are put into a passive and overloaded situation, thence they are unable to think deeply and thoroughly, to read more references and to participate in various extracurricular activities. These are not helpful to fostering the independent thinking , initiative and creative spirit of the students, and on the contrary ,exerting restraining effects.

Physics course in secondary school is a course the students are interesting in and at the same time conscious of the arduousness in studying. The physics speciality in universities and colleges is in the same situation. Appropriate way of teaching will enhence the interest of students in physics and develop their initiative as well as creativeness, thus the students can not only grasp firmly the fundamental principles, experimental methods and skills in physics, but also get the ability to acquire and to evaluate new knowledge by themselves as well as the ability to analyse and solving problem faced through their comprehension and using of knowledges concerned. To achieve this aim, the following measures should be adopted, i.e. more flexibility in formulating teaching program and outlines of courses, refreshing the contents of courses, raising the academic level of teachers through continuing education and replacement, and reforming the teaching methods in accordance with the characteristics of students. Physics teachers in China have paid attentions to these points and make remitting efforts, and it is expected that these efforts will make contributions in bring up highly qualified physicists and in raising the scientific and cultural level of the whole nation.

ON THE QUALITY EVALUATION OF PHYSICS COURSE IN ENGINEERING COLLEGES

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Introduction

In China, the reformation of education system has been pushed forward rapidly in recent years. The trend is to encourage the universities and colleges to run their schools in their own ways independently. Under such circumstance, it is necessary to strengthen the macros-copic supervision overlooking the high education. Thus, developing a scientific quality evaluation system, adaptable to the conditions in China, for engineering education becomes imminent. As a matter of fact, studies on this issue and trial attempts have been conducted in some institutes.

Evaluation of high education is a complicated process, it may be carried out at three levels, namely, evaluation of an institute as a whole, evaluation of a discipline under an institute and evaluation of a single course. This paper is devoted to the evaluation of the course, general physics.

Objective of Evaluation

The course, general physics, consists of two parts, the theoretical part and the laboratory part. Sometimes, they are separated into two courses. The objective of evaluation is two-fold: firstly, to run an appraisal over the quality of teaching and learning for encouraging the institutes of high grade for further advancement and stimulating those of low grade for making up their shortcomings; secondly, to provide a chance for exchange of experiences between institutes so that they can learn merits from each other. In addition, the evaluation also has the function of urging the administrative staff to pay attention to the standing of the course and give necessary support to the teaching staff and teaching facilities for continuous upgrading of the teaching quality.

Basis of Evaluation --- "The Basic Teaching Requirements"

The main point of the quality evaluation of a course is to make clear what the fundamental task of the course is. The dividing line between the qualified and the non-qualified lies on that. The "Basic Requirements for General Physics Course of engineering Colleges" drafted by our government is the minimum requirement which should be fulfilled by all engineering colleges.

It is formulated according to the object and calibre set for training engineering college students and also with consideration given to the position of physics course in the training program. Therefore the "Basic Requirements" is a document guiding the teaching program of a discipline as well as the teaching syllabus of the course. The content includes knowledge and ability required. The evaluation should also accord to the "Basic Requirements". We feel that the margin of minimum requirement need be clearly delineated to clarify the qualified standard. And in order to meet the various conditions of different colleges, the minimum requirement should be set at an appropriate level instead of a high one.

Scheme of Evaluationn

In making the scheme, several points have been upheld. It is deemed that the teaching quality of a course not only depends upon the work on the teacher's side, but also upon the attitude of the students towards learning and the facilities provided by the institute. Thus, the evaluation need be extended to those phases. Since teaching quality is affected by many factors, we can hardly rely upon the scores of some examinations for proper évaluation. For the conveniençe of comparing one institute to another, we are trying to quantify most of the factors considered in the evaluation, but for those of fuzzy character, we give only crude rating. Because of lots of fuzziness and uncertainties existing in the evaluation, we prefer to make it crude rather than precise and incline to give separate rating which might incluce misimpression to the institute.

In view of the above statements, we have established an evaluation system which consists of three phases composed of ten items and each of them may be subdivided into a number of sub-items. Each item is given a rating index as the result of evaluation. In the following are listing the evaluation phases and items.

Phase I. Evaluation of effectiveness of the course

ItemI-1 Evaluation of the problems and the score of the examinations in the institute in question

ItemI-2 Scores of examination given by the specialist panel, attended by randomly chosen 10% students

ItemI-3 Opionions reflected from the succeeding courses

Phase II. Evaluation of teaching process

Item II-1 Teaching work --- pre-class work, classroom lecture, homework etc.

Item II-2 Teaching reform and teaching research

Item II-3 Teaching management --- regulations, attitudes of teachers and students

Phase III. Evaluation of faculty and facilities

Item III-1 Faculty --- present composition, replenishment,upgrading

Item III-2 Facilities --- laboratory, library, teaching equipments

Item III-3 The position of physics course in the disipline program --- voice of physics teachers , credit hours of the course

Item III-4 Service to teachigg --- printing of teaching materials, maintenance of classroom and laboratories, etc.

The rating of the evaluation is made in two steps. The firstt step is to give each sub-item a crude rating marked by A, B and C. The second step is to convert the crude marks into points. The full mark of a phase is 100 points which is distributed to the belonging items and further distributed to the sub-items so that the phase rating is the sum of item ratings and the item rating is the sum of the sub-item ratings. Rules are set for converting the crude marks A, B, C into points. As indicated before, the phase rating are not added to give overall rating, for the purpose of clarifying the merits and shortcomings of the evaluated course in order to promote advancement. The evaluation scheme for laboratory course differs somewhat from the above. The details of the evaluation is illustrated by the following case study.

Case Study

In June of 1986 it was decided to choose three engineering institutes in Heilongjiang province to proceed the quality evaluation of college physics as case studies. The provincial education committee organized a specialist panel to conduct the evaluation.

The procedure is as follows:

1. Each member of the specilist panel received a self-appraisal report from the evaluated institutes, listened to the explanation of the report, examined and verified the report with the attached materials.
2. The members of the specialist panel attened lectures on physics and laboratory classes and organized discussions with students.
3. Examined students' homework and laboratory reports selectively.
4. Visited physics laboratories and demonstration laboratory, inspected the experimental equipments.
5. Organized discussions with physics teachers and administrative staff.
6. For the evaluation of laboratory course we randomly selected a portion of students to take a written test and a manipulating test. The result relatively reflects objectively the quality of learning. For the theoretical course each of the three evaluated colleges took a set of problems essentially of the same level. The students were also randomly selected (about 10%). Evaluation of effectiveness is the core of the entire evaluation because other phases of evaluation all aim at a good teaching effect. Therefore this phase cannot be neglected, but it should be reliable and simple.
7. Members of the specialist panel studied the self-appraisal report of the colleges and gave rating independently. Finally an average score was given to each phase for each college.
8. The specialist panel wrote a detailed comment for each college.

The case study now is primarily completed, the "Basic Requirements" and the scheme of evaluation are to be revised.

Supplementary

1. It is important to assure accurate evaluation with minimum amount of work involved. Through practice, we find that the self-appraisal by the institute being evaluated plays an important role in the evaluation. It is closely linked with the daily teaching composition and administrative work, thus reflecting the whole picture of the course. With a good self-appraisal, much time could be saved for the evaluation panel, it should be pointed out, though, that any attempt of presenting false evidences should be prevented. In practice, we also found that good self-appraisals match the marks in the evaluation fairly well, so self-appraisal serves as a good basis for formal evaluation.

2. In practice, many teaching staff complain that quality evaluation conflicts with the education reform. They say that the evaluation indices act like a "baton" which directs people towards a unique target and prevents new ideas that may affect the grade of evaluation. This is worth to noticing. A way of avoiding the conflict is putting the successfulness of reform as an index of evaluation to encourage reformation.

3. The aspect of teaching processs is a vital item of evaluation. Through visiting lectures, discussing with students and teachers and other forms of investigation, we can comprehend the general aspect of teaching. Opinions of specialists obtained by visiting a few classes may involve subjective impressions, so their opinions should be combined with those of students and teachers and with the self-appraisal by the institute in order to yield good results. Furthermore, the ability of students in learning not only depends upon teaching quality but also upon their attitude towards study; this ought be counted in the evaluation.

4. Composition of the teaching faculty is another important factor in evaluation. We found that replenishment of staff becomes a problem in colleges located in border areas of the country. The college graduates do not like to take a teaching job in small or medium cities. We were told by the administration of a college that for the period 1982-1985, only one out of 12 physics graduates from other universities took the teaching position assigned to them. This deserves the concern of the government and the public.

5. The scientific standing of the teaching staff influences the teaching quality and most of the teachers wish to have academic career besides teaching. Therefore, it is advisable to develop research work in all kinds of colleges for the benefit of stabilizing the teaching staff and upgrading the teaching quality.

Acknowledgement

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CLIMATE AND WEATHER --A PHYSICS COURSE

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abstract

Usually physics courses are structured in a "classical" way:

mechanics, optics, electricity, heat,...

In such a rigid scheme the basic principles and fundamental ideas of physics can be taught (and understood) in a very complete overall way. Nevertheless many pupils (and some students, too) are not very motivated and attracted by such a concept of teaching.

We have developed a 10-lecture-course on "Climate and Weather", which combines the teaching of basic principles of physics (heat, radiation balance,...) with applied interdisciplinary aspects (humidity, temperature and well-feeling, co_2-problem,...). In our lecture we shall outline the principles of such a course and give some concrete examples.

IMPLICATIONS OF PHYSICS EDUCATION RESEARCH FOR THE CLASSROOM

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Abstract

The study of intuitive (spontaneous, alternative, common sense) conceptions related to natural phenomena is presently one of the faster expanding fields of research ia Physics Education. Results of our current research related to light, motion and heat will be presented, discussing the different methodologies used to collect data: 1) clinical interviews (piagetian); 2) collective interviews (non-inductive physics demonstrations in class); 3) batteries of problems dealing with familiar situations and 4) interviews using instances published in children's magazines. The advantages and implications for the improvement of science teaching when participative research in developped with teachers (in-service and pre- service), will be discussed from several points of view: a) interest of cognitive psychology enhanced; b) familiarization with non-directive disciplined forms of class interaction; c) conceptualization of physics deepened.

THE CREATION OF SUPPORTIVE ENVIRONMENT FOR LEARNING PHYSICS

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Abstract

Pupils potential to learn physics is affected by their previous experience with nature and by kind and intensity of interactions with other children, with parents, toys, tools etc.

This knowledge is as individual as hereditary factors are. Therefore, individual differences, appearing as the pupil's personal informal and intuitive pre-physics and related thoughts are the most important boundary condition for learning physics. The efficiency of teaching physics to a class of thirty pupils depends mainly on two items:

- the teacher's knowledge about elements which fit or unfit the mental equipment of learners,
- the teacher's ability to create a supportive environment for learning physics.

The paper deals with both items, but the accent is put on the second one.

Problems and methods of Evaulation in the Teaching and Learning of Physics

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There is a profound danger that 'evaluation' becomes an end in itself. Physicists and/or society at large become concerned about the quality of learning of physics that is taking place. They also become concerned if they deem the number of students taking the subject to be insufficient to maintain the subject or to service the economic requirements of that society. Inevitably and probably rightly, this is linked to the quality of teaching received. They ask themselves what can be done about this and they come up with a series of answers, some concerned with the content of courses and some with the quality and standard of teaching. Two panaceas are then proposed. Make the Physics more exciting, more relevant, more applicable, more accessible to all students especially, of course, girls [in the United Kingdom making physics more attractive to girls is a growth industry in education] and your content problems are solved. As part of this exercise you postulate that there are entities called 'processes of physics' which can be identified and taught in such a way that content, especially difficult conceptual and mathematical content, can be jettisoned to allow these processes to be developed. Having done all this provide in-service teacher education for those teaching physics in order that their teaching improves. If and when these twin reforms are implemented, the argument appears to run, the quantity and quality of learning of physics will inevitably improve.

There are some major logical non-sequiturs in this argument. It is by no means clear that changes in the content of courses will improve either the numbers studying physics or the quality of learning achieved. There is after all little point in knowing the industrial applications of a particular piece of physics or being able to implement some hypothesised 'process' of physics if, when the crunch comes you can't apply Newton's Laws to solving a real problem involving Physics. It is also not necessarily the case that providing extra training for teachers teaching physics will have any significant effect on how well physics is taught. And even if it is taught 'better' it does not follow that it will necessarily be learnt 'better', unless better teaching is defined in purely operational terms. That is to say if the learning improves then the teaching by definition must be better. But what is it that is being learnt? And how is it known that the learning that is taking place is better? How are the criterion for determining what needs to be learnt and its assessment set up?

All of this leads to calls to 'evaluate' the teaching and learning of our subject. If a car goes wrong or you have a stabbing pain in your side then the relevant mechanic is called in to (a) diagnose the fault and (b) cure it. In the case of a car mechanic this can mean an adjustment to a gear, a replacement of a part, or simple lubrication. In the case of a body mechanic - doctor - the process is rather similar except that the situation is often easier to deal with. The body actually cures itself of many ills. All the doctor often has to do is to provide a pain killer while the body does its own servicing!

Evaluation of teaching and learning implies diagnosing what is wrong and then curing it. Knowing what is wrong in turn implies knowing what is right. Before we can evaluate teaching and learning we need to have in front of us models of what good teaching and good learning are.

I have such models and no doubt so have you. Good teaching is of course what _I_ do. I don't always achieve it but when I do I know its good teaching! By the same token I can recognise good learning. It is what _my_ students achieve when I am doing _my_ good teaching. The trouble is that an observer might think it to be awful teaching and that in any case I am trying to teach the wrong thing - an observer might profoundly disagree with me both about what constitutes good teaching of physics and indeed what constitutes physics. It does, therefore, seem self-evident that before we can evaluate either the teaching or learning of Physics we need to have some consensus view of both what constitutes good teaching and what constitutes an acceptable defining statement for physics.

What does constitute good teaching? Is it possible to generalise? Is it a matter of presenting information clearly and coherently, or is it a matter of getting students to think? Is it a matter of giving well thought out notes, or a matter of encouraging and managing the independent learning of students? Is what counts as good teaching with a group of twelve able students the same as what counts as good teaching when faced with a class of fifty or more students of diverse ability? Is what counts as good teaching of 15 year old school children the same as what counts as good teaching to university students?

The catalogue of questions about what constitutes good teaching is endless. This does not mean we cannot recognise very good, or very bad teaching when we see it. Often we can identify the elements that make it either good or bad. But the extremes are not the problem. Most of us, as teachers, sit somewhere in the middle of some sort of, hopefully, skewed distribution of teaching performance. What we cannot expect is that different observers, each with their own subjective view of what constitutes good teaching, will agree on our position within that distribution. Faced with that, how do we even begin to evaluate teaching? And even if we succeeded in this impossible task, how might we then go on to use that evaluation to improve teaching, assuming that the reason for the evaluation is to provide a basis for such improvement.

How independent is good teaching of good learning? Presumably the only reason for being concerned with teaching is that learning should be improved. But what is it we want students to learn? And how do we assess whether they've learnt it? And how do we then further assess if changes in the way teaching takes place actually improve learning? And finally are there other factors which are more important for improving learning than improving teaching?

It is obvious from the above that those who wish to evaluate learning are in grave difficulties. In England we are currently experiencing a 'knee-jerk response' to these and related problems. Traditionally there has been little central direction of the curriculum and certainly no centralised interference in what is taught within particular subject areas. All that is now changed. Physics is no longer defined by physicists; it is defined by government appointed committees intent on ensuring that what is taught within the physics curriculum meets that government's concept of what physics education should be about.

Simplistically this might be seen as making the evaluation of learning, and therefore teaching, easier. Whether such evaluation is of any relevance in improving the learning of physics by students is another matter. What indeed do we mean by 'improvement of learning' anyhow and what are our reasons for wanting to improve it?

Improved learning is usually simply equated with getting better examination results. However, at a research level it can mean exploring the way students learn and altering the examination to better fit the theoretical constructs which those doing the research provide. Such researchers would argue, I think, that important aspects of learning physics cannot really be measured by conventional examinations and that other more diagnostic evaluations should be attempted if improving learning really is our aim. But if we change what we are trying to do how do we know we have improved? Valuable as research may eventually be in changing our perception of what we should be learning, and therefore teaching, a student's, and society's, perception of improvement is measured in percentages.

One problem with these percentages is that they can only measure, however imperfectly, past performance. It is what the students have learnt that examinations measure. Now examiners are very clever people and recognise that students are not just expected to learn facts on a physics course. Examiners also have to test students' abilities to apply those facts, to perform practical skills, to design experiments, to present and process data, to discuss application and social implications of physics and so on. And so they devise ever more complex and clever testing systems to test everything the course designers claim they want students to learn. They then effectively destroy almost all the information they have collected by conflating it into a single grade or percentage. And all this percentage tells us is what the student has done not what he or she is likely to do in the future. Yet the ONLY point in any test of past performance is its validity as a predictor of future achievement. There is absolutely no evidence that sophisticated examination or evaluation techniques are any better at achieving this validity than any other examinations set by physicists to test students' understanding of physics. Anyone who really has faith in formal techniques of assessment, and therefore evaluation, is recommended to read a recently published commentary on Examinations(1) written by John C. Matthews who has been involved in U.K. examinations for over a quarter of a century. It is salutory reading.

Does all this mean nothing can be done about improving teaching and learning? One profoundly hopes not. But it does mean there are no formulae, no easy panaceas which can be offered. Most research into learning takes place in situations in which enthusiastic, good, well qualified teachers try out their ideas on small groups of pupils in well resourced environments. In my own University, the Children's Learning in Science Project(2) takes as its starting point the self-evident truism that in teaching something new it is important to take into account students' perceptions of what it is you want them to learn. How this then translates to teaching groups of 50-100 students working in very much less favourable conditions, often with less well-qualified teachers than we are privileged to have, I do not know. I therefore want to finish this paper by suggesting a heresy. There are higher priorities for improving the learning of physics than evaluating it!

First and most important, a necessary but not sufficient condition for the improvement of learning, must be that the students actually want to learn physics. Now, fascinating, exciting and important as all of us here know Physics to be, we need also to recognise that it is our career. Physics has been good to us. It has given us a living, and a status. Young people need to believe that Physics is important to them. If society rewards those that do well in Physics then learing has a chance of improving; if it doesn't, th nothing we, as physicists, do to improve the quality of that learning will ha anything other than a marginal effect. In my own country, despite the rhetor of government about the need to produce more scientists, technologists and engineers, the reality is that the rewards are going to those who manipulate money. Young graduates know this and are reacting in ways that reflect this. And who can blame them? It is a necessary precondition for improving the learning of Physics that the learning matters to the learner. There is no po in having superb teaching materials if no one wants to learn from them.

If this condition is met the next necessary condition is to provide the learner with good teaching. Now certainly in my own country there is a gener acceptance that there are not enough good teachers to go round. Furthermore if a change in what is to be learnt is required, or a change in teaching styl called for, it is necessary to provide extra up-dating and training for all teachers. This is both expensive and logistically difficult. Increasingly we are being driven to accept that the way forward must be to make increasing use of distant-learning techniques. Use of video materials, computer program et al may become increasingly important as ways of ensuring that what is to be learnt is presented in ways which not only ensure the physics is correct but also in ways which take into account our understanding of learning processes. This does not of course go all the way. In an ideal world we woul want to take into account different styles of learning and tailor our teachin to those styles. There are those working in the field of Computer Assisted Learning who are beginning to claim that it should in future be possible to write programmes which cater for a variety of learning styles. Although the level of provision required for such developments would be prohibitive, as a research tool for developing video based materials presenting phyiscs in ways which match learning styles these developments may have value. Realistically this is not on. However, the artifacts of Information Technology - televisio video recorders, computers et al all have the potential for ensuring that tho wishing to learn physics at least have that physics presented effectively. Those who wish to evaluate learning will then actually know what has been taught. Good presentation is not all there is to teaching and learning by any means. But at least its a starting point and if we don't have that how can we begin to evaluate anyway? Physicists, after all, are never happy when they have too many quantities varying, especially quantities they can't actual define.

In this paper I have tried to introduce a degree of scepticsm first about the possibility of evaluating teaching and learning and second about whether evaluating them is important anyhow. Finally I have suggested that the way forward may be to explore ways of making use of modern information technology systems to present physics learning materials effectively. In doing this we should of course ensure that two things happen coincidentally. First the physics is presented well and second it is presented in a way which takes due account of what we know about the way students learn. This seems to me to be the way forward for physics education not only in any country which is short of teachers but as a matter of principle.

In Western societies Information Technology could justifiably claim to have been invented in 1456 when the first printing press was invented. No doubt that Technology was available here earlier. The printing of books transformed the availability of what people could learn. Today television and video provide a similar opportunity. It would be appropriate if physics, on which this whole new technology depends, becomes its major beneficiary.

(1) Examination: A Commentary. J.C. Matthews. Allen & Unwin (London) 1985

(2) Children's Learing in Science Project (C.L.I.S.P.)
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UNIVERSITY PHYSICS TEACHING AND PHYSICS EDUCATION RESEARCH

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We have either been engaged in physics teaching or doing teaching research at the university education fore-front for many years. We are glad that our government has made the resolution in the reform of the system of education, which is soon to be flourishing again.

Education, principally a specific social demand, is the activity or the process of educating people. Different eras demand differently. It is mid-eighties by now. What kind of personnel should be educated in universities for our modernization program? What sort of reform in introductory physics—an indispensable fundamental course in engineering universities—should be adopted to meet the demands? What will be the principles of the reform, how to carry out the reform, all deserve careful studies.

(I) Teaching reform should be based on profound study and research. A review of existing problems should be the prerequisite to any reform. We suggest a four point approach:

(1) Studying pedagogy principles. Guided by the principles and combined with teaching practice, mutual collaboration can be established. Making conclusions without theoretical guidance and based on one's specific experience might only fall short of the correct goal. Teaching practice will be better seated if based on pedagogy principles, and spiral approaches to perfection might be achieved after following the principles.

(2) Studying teaching materials. To expand the potentials of the basic theories in university (introductory) physics to apparent results in technical innovations and to combine properly fundamentals and frontiers, it is necessary to survey meticulously various teaching materials available at home and abroad and also the trend of contemporary science and technology to render scientific evidence for the reform of contents. In recent years, some countries have modernized the contents of university physics, featuring early introduction of concepts of relativity and quantum mechanics, expanding in time the weight of modern and statistical physics. Their merits certainly deserve our attention.

(3) Studying teaching methods. To develop students' capabilities, accumulating knowledge and building up ability are inseparable, so are methods and contents. Grasping knowledge is the basis of bringing up the capabilities. We should study what methods should be adopted in university physics to enable substantial growth in the students' capabilities.

(4) Studying teaching media and facilities. To make good use of demonstrative experiments and up-to-date teaching aids, such as films, videos, programs and slides, to give students vivid, distinct, and deep impressions and to excite both the students' interest and zeal.

Admittedly, the approaches are interwined and not individually discrete, the purpose is to tell teachers the direction of reform, its approach, prime aim and final goal in the long run. Our opinion in the reform of university physics is as follows.

(II) It is proper time for university physics' reform

Recently, the Education Commitee of our country decided not to standardize an outli for any individual course but to set up basic requirements for each. It serves as the basis for planning curriculum and course outline for any individual course but to set up basic requirements for each. It serves as the basis for planning curriculum and course outline for every university, as well as the basis for text compilation and course quality assessment. Its aim is to encourage better and more flexible teaching with pronounced special features. Therefore, the inscribing of basic requirements should follow the goal and quality requirements of university level engineering education. The basic requirements should specify the relative position of the course in the process of educating personnel, its function and task; the extent, subjects, structure, requirement and level, the time allocation, etc.

Our discussion will begin from the basic requirements of teaching, the course outline and textbooks.

Why is it thought of as the proper time for university physics' reform? Form the Education Committee of the government, among teaching staff of all universities, it has been understood that standardised outlines are no longer to be observed to encourage "better and more flexible teaching". Teachers feel strongly that the contents and structure of physics for engineering universities should be modified. To the propagation of science and technology, the outcome of physics still plays decisive roles there of.

(1) Many teachers hope to outgrow the old framework to include something new when putting down the basic requirements, to embody coarse, fine, detailed and abridged patterns, to renew capability cultivation and to attract teachers to love their jobs and students, their study. We feel it a good time for all these. We should review our previous experience and slips, be fearless to create things new and fumble through our own way. Naturally, it might be tedious and risky along the new route. Different aims, levels and periods of reform should be tested, such as whether the requirements of today could last three to five years. Opinions, practices are encouraged and to be interchanged and learned. Do our best to raise the teaching quality and level to cope with the up to date situation.

(2) Bringing forward basic requirements in university physics is only a prerequisite. To bring on better and more flexible teaching, every university is to put down its own syllabus, which specifies not only the teaching requirements but also the systematic framework of university physics, with clean lines and distinct braches; the features of freshman and sophomore tackled; the characteristics of the course; the level of knowledge to be grasped; exacting skill build-up program of students and encouragement to bring out the originality and creativeness of teachers to their up most.

(3) The textbook is important because through the contents it reveals the requirements of the course. Firstly, it should be essentially new, but

care should be taken in understanding the meaning of modernization to be able to renew correctly. From pedagogy's view, general concepts, characteristics and configurations should be given prior to introducing new parts, to offer students bird's eyeviews of the subjects before detailed treatment of chapters and sections. The compilation of text can also follow these approaches by enriching various introductory sections (not the chapter of introduction) and making them more animated. Expending a few lines and time but helpful to the students' grasping of knowledge and forming of deftness. Secondly, in the selection or cancellation of materials, high school background should be considered to be truly stepped up in level, to give students something new they can actually learn. For instance, the students' background in mechanics and electricity are fair, but not exceptionally good in combination and sophistication. Time can be spared for wave motion (including wave optics) and modern physics. The preceding, i.e, mechanics and electricity, takes about 40% and the latter 22% each. For heat and thermodynamics, emphasis should be put on microscopic descriptions and statitics and more on entropy. Then, the text should have ground for the points of methodology in teaching, such as idealized models, comparisons and contrasts, conclusives and deductives, etc.

The basic requirements, course outlines and texts are a mutually collaborating and promoting trio, putting together with appropriate teaching method, a new realm can be attained. However, these requirements, contents and methods should be guided and organized by pedagogical principles.

(III) Teaching should observe their principles and regularities

It has been mentioned before that the importance of studying pedagogy, the principles and regularities of teaching should be studied prior to others. In principle, education and teaching are more or less different but closely linked together. Whenever teaching, education is also impressed. While teaching is not exactly education, if a teacher did not know its principles, he would not be able to make good use of them for education.

Teaching is a process, formed by a cooperation between two sides, teachers' teaching and students' learning. The process is executed according to predetermined aim and planned course employing teaching principles and applied to the educated to meet the standard of personnel asked for by the society. We should study education theories, first the teaching principles, which do not alter after people's intentions but rather always in existence. There are three fundamental teaching regularities:

(1) Teaching benefits teachers and students alike. Teaching and learning are mutually promoted. There are learning in teaching and teaching in learning. People who teach and those who are taught are supplementary to each other.

(2) Role of education in teaching. This is stated threefold. First, scientific knowledge is educational in itself. Second, the achievements of science, the tedious and hard undertakings of scientists and their painstaking efforts exercised toward discovery of success all set excellent

examples to encourage students' diligence. Third, the conscientious attitude of teachers in teaching and research work influences students potentially. These are all educational ideals.

(3) Teaching is linked with progress, here progress being the psychological development. Teaching and progress are not discrete but related. Psychological progress should be considered whenever one is teaching, which would otherwise be limited experience only. They are also combinations of knowledge accumulating and ability forming, succeeding the explored and pursuing the unknown.

From the regularities, the five principles of teaching are suggested:

(a) Mobilization of both teachers' and students' aptitudes. From pedagogy, education is the main factor in promoting students' psychological maturity. It is not simple and monotonous "give", but achieved through students' ardent activities. The teaching process is completed by the activities of both sides, the teaching and the taught.

(b) Accumulating knowledge and building up ability coordinated. Their relationship has been mentioned before. There are three kinds of abilities. First, perception, which is the ability to sense new things, observation and analysis of facts and experiments and the potential to acquire knowledge independently. Second, thinking, to upgrade from things felt to things recognized, abstract thinking and logical reasoning, analyzing and solving problems, applying mathematical tools to solve physics problems, concluding summarizing and presentation. Third, ability in practising and creativeness, undaunted spirit of exploration and adaptibility, suggestion of new points, new methods and new hypothesis.

(c) Maintaining a level of "speed" and "depth" in teaching, leaving students tense but absorbed. Laying "steps" in students" studying to fill them with tense minds, yet their abilities in thinking improved, responses speeded up with enhanced results.

(d) Combining teaching with practice.

(e) Adopting both a uniform standard and individual tutorship for the talented.

The teaching principles listed are certainly not the only ones. However, in the teaching of university physics, if the principles are carried out purposefully, taking into consideration the specific conditions, good results might be expected. To maintain a level of depth means students are to climb up the steps to learn things new and be interested, a level of speed calls for the students to struggle to get ahead.

(IV) Physical education research is the mainstay of the reform of university physics.

Education research work for universities, studying the particulars of individual courses, its importance is not yet fully appreciated, attention from vast teaching staff is urgently advised to have some promotion in teaching reform.

Physics education research is a multilateral work, involving physics, also closely related with pedagogy and psychology. From a worldwide scale, it is still at an infantile stage. However, many countries have universities offering postgraduate studies leading to master's and PhD's degrees in this field. There are also organizations engaged in interchanges and discussions, such as "International Commitee of Physics Education" (ICPE, a subordinate of IUPAP) which for two or three recent decades, has organized annual conferences. In America, there is the American Association of Physics Teachers (AAPT) with two conferences annually; in Great Britain, a periodical "Physics Education", etc. It illustrates the importance of physics education research and has been recognized by scholars of the world. Recently, more than twenty universities in our country begin to offer postgraduate programs in physics education research, "University Physics Education Research League" has also been organized.

(1) Physics education research, as a course, should have theories and make advance through practice. One of the authors has been in America twice, 1980 and 1982, to visit 13 universities. Both Berkeley, U.C., and Washington University have physics research organizations and doctorate programs engaged in research work. To promote students' "capabilities in science", Washingto University has a special physics course, the teaching material and method of which are all original. After taking the course, the students find their abilities appreciably improved. We hope to be able to borrow two points from them. First is the idea, which is put to practice and later effectively assessed; evolving students' enthusiasm while aiming at higher steps and prompting them ahead. Second, their work is creative and emerges from the fruit of research work, not blind guessing. Another example is that in recent years many American high shoools adopted Havard Project Physics with a good many aims in mind; Helping the students to recognize the physical world and related knowledge, teaching essentials instead of separate topics, providing immediately useful experience in science, bringing into play teachers' role in teaching, etc. Then, multi-measures of teaching have been taken, with new textbooks, supplementary reading materials and other up-to-date teaching media. These meticulously planned, carefully arranged programs are good attempts of education reform. We should also design original attempts based on our own particulars.

To improve physics education research gradually, two points should be noticed:

(a) Research projects should be in accordance with problems and be able to combine education theory with teaching practice effectively. The problems might be: the contemporary trend of science and technology, the requirement of personnel training, analysis and assessing of texts at home and abroad, scientific evidence and practibility of text reform, the correlation between the accumulation of knowledge and ability building up, the function and position of university (introductory) physics for senior engineering personnel, reform while taking into consideration the teaching principles to attain high speed and depth, the application of modern teaching aids, etc. The results should be accompanied by persuasive statistical figures.

(b) To uplift this subject, indefatigable spirit is a requisite, mutual support and collaboration are also necessary.

(2) Raise the quality and quantity of postgraduate students in

physics education research. To thrust the sprout to mature, young ambitious people interested in this field will be accepted and trained to study and explore as graduate students.

Our "physics education research" directors' team has admitted five sessions of graduate students since 1982, through our work, some views have since been formed. Futher discription about this can be read in the other article of mine "On the Reform in Physics Teaching, Research of Physics Education and the Influence of Technology Developement."

The main goals in the program for these graduate students are: systematic physics background and necessary laboratory techniques, also certain university education theory to be put together with physics education research, familiarity with the trend of development of science and technology in the specific field of research, beginner's but independent capability in physics education research, well-to-do in pursuing spirit and suitability of teaching in universities.

In the program, advanced theoretical and lab courses, as well as education theories are arranged. In addition to common fundamental courses, there are intermediate courses: numerical analysis and data statistics, advanced quantum mechanics (including group theory), university physics education, modern physics lab principles and methods. Required speciality courses are advanced pedagogy, classical or modern physics topics study, application of computers in physics, university texts study, history of physics, etc. Optional courses include educational psychology, modern teaching media topic study, etc.

Attention has been given to the training method to enable students to investigate literature for topic presentation freely and indepently. The thesis projects are devoted to the combination of theory and practice, for ensuring non-biased teaching work later. These are just the beginning, to be improved incessantly. It is believed, that after collaborations, mutual help and through the effort of all, things will be better onward.

Physics education research cannot be completed by just a few people, nor in just a few years. Through incessant "climbing up the slopes", we can expect to reach a more beautiful realm.

TEACHER TRAINING IN DEVELOPING CONTEXTS

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Abstract

Social setting conditions strongly modulate problems on physics education such as: the training and updating of teachers, the production and testing of appropriate didactic materials and, the implementation and evaluation of educational projects. We discuss few activities undertake during the last ten years and consider the role of research on physics education in the context of a developing country. We also comment on more recent work related to: a) a physics teachers training program under the sponsorship of the Ministry of Education in Mexico; b) the creation of a research group on Science and Technology Education at Iztapalapa; c) the consequences of the International Seminar on Microcomputers in P Physics Education (Mexico City, January 1986) and d) the concept of network planning for cooperative projects and the Inter-American Conference on Physics Education to be held in Mexico, July 1987.

AN INSTRUCTIONAL STRATEGY USING MICROCOMPUTERS FOR THE TEACHING OF MECHANICS

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Abstract

The research we present is part of a national project, dealing with use of computers in Physics teaching, promoted in 1985 by the CNR (Consiglio Nazionale delle Ricerche). The project involves a number of researchers in different Italian Universities and it is aimed to the production of computer packages designed to improve the teaching and learning of Physics in high school.

We elaborated an instructional strategy based on a wide experimental activity of the students strongly integrated with computer simulations. The strategy we developed has been applied to the study of the free fall of an object and seems to be effective in enhancing the understanding of mechanics on the part of high school students. Our computer programs run on APPLE II, IBM PC and Olivetti M24; an English version of the student-computer dialogue is available.

PHYSICAL INSIGHT IN CLASSROOM LECTURES

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Traditionally, Chinese professors are highly conscientious in doing their duty, prepare elaborately for all phases of teaching activities. The students are cooperative, do what the professors assign, work diligently. So the overall quality is not bad.

In recent years, emphases were laid on heuristic teaching and inteligence development. So far, so good. But, there is often a tendency to push things to extremity, to push things beyond their limits of applicability. This is a tendency to negate traditional teaching totally.

Much of the reproach is concentrated on classroom lectures. It is said that lectures simply press pieces of knowledge into students. Thus all lectures are denounced as MAN-TANG-GUAN (a Chinese expression meaning "to compress into the memory of the audience all the while"). Some declared that lectures should be replaced by self-taught system. Let me quote one of such comments: "All what I got from good lectures was eventually forgotten. On the contrary, bad lectures forced me to study by my own efforts, in the course of which things were gained and never forgotten." In other words, professors who give bad lectures do the students good, while those who give good lectures do no good. Perhaps, there are grains of truth in it. Extraordinarily excellent students would like to study at their own pace, and they can raise meaningful questions of which they have no serious difficulty to find out answers through their own efforts. Self-taught system suits them well. However, in general cases, such comment spoils good tradition, hurts professors' emotion, reduces their conscience. It also indulge students to be absent-minded in classes (since they regard the lecture as MAN-TANG-GUAN). Diligence gives way to loose.

A Chinese proverb goes that "No piece of gold is absolutely pure, no one is perfect person." If you mean to find fault with something, you can always do. Indeed, we can find dull lectures, simply reciting what are written in textbooks, giving students no help, neither for physical comprehension nor for solving problem. They deserve the name MAN-TANG-GUAN." Yet I don't think so do all lectures. Once I visited a class. One of my colleagues gave lectures on electricity and magnetism. The lecture attracted the attention of the class. He raised interesting questions, left to the students to think over. The followings are two examples: 1. "Why do birds resting on high voltage wire get no electric shock?" 2. "The vertical electric field near the surface of the earth is of the order of 100v/m. Thus, there would be a voltage of more than 100 volts between the top and the heel of a standing person. Why is there no shock to him?" These questions are keen, hard to answer without serious ponderation, by which the students get better comprehension of basic concepts such as electric potential and potential difference, capacitance and spurious capacitance, etc. I myself teach mechanics for years. In mechanics there are also many interesting and keen questions, which will guide the students to better comprehension." Here I give some examples: 1. "People discuss radius vector $\vec{r}$, velocity $\dot{\vec{r}}$ and acceleration $\ddot{\vec{r}}$. Why don't people discuss $\dddot{\vec{r}}$?" 2. "When you play on a swing (Fig. 1), how can you swing higher and higher?" 3. "A weight W is supported by a flexible and light string as shown in Fig. 2, then the tension T in the string is found to be $T = W/2 \sin\theta$. For $\theta \to 0$,

$T \to \infty$.* This seems to mean that even the lightest dust particle (extremely small W) can break the strongest string. Do you think it is really so?"

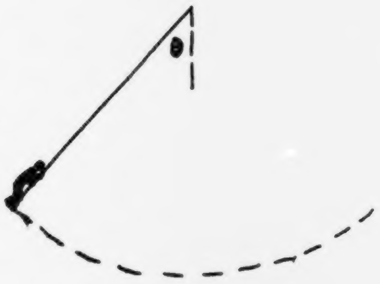

Fig. 1

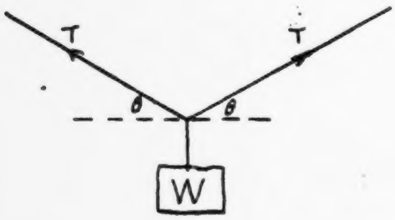

Fig. 2

As to intelligence development, classroom lectures also have their own role to play. In the article Freshmen Mechanics Should Guide the Freshmen to Pass the Turning Point Smoothly , I pointed that freshmen are used to treating known quantities but not good at treating unknownt, that they can't differentiate scientific terms from words in daily life, and that they are not good at vector composition and resolution, and that how we guide freshmen to overcome these shortcomings. In fact, the intelligence development and knowledge transmission should be incorporated with each other. It is hard to imagine the intelligence without knowledge as its foundation; and it is quite seldom that a physics lecture gives unrelated pieces of knowledge without illustrating where they come and what role they play in solving physics problems.

Some of classroom lectures maybe MAN-TANG-GUAN, but most of them are not, I suppose.

Good lectures often give deep insight into the question under discussion. This is a merit over self-taught system. By solving the equation of motion of an accelerating car (Fig.3), it is found that the supporting forces at the front and rear wheels are $N_1 = m(g-ha/L)$ and $N_2 = m(g+h\,a/L)$ respectively. Probably, most of the students have no difficulty here, but few of them can find a clear-out physical picture how is N_2 greater than N_1, while experienced lecturer may give in his lecture the following picture. The force that accelerates the car is the frictional force F at rear wheels. The torque of F about the center of mass is counterclockwise, giving the car a tendency to rotate counterclockwise. It is this tendency of rotation that causes $N_2 > N_1$.*

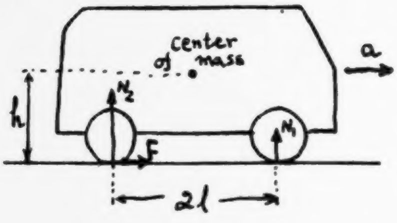

Fig. 3

Especially for key and difficult points, should the professors search for such clear-out pictures through repeated deliberation from various points of view.

For example, the motion of the gyroscope is quite a puzzle for beginmers. The difficulty may be traced back to the tensor of inertia present in the expression of angular momentum. In particular, when a rigid body rotates about x-axis with angular velocity ω_x, it possesses not only an angular momentum $I_x\omega_x$ about x-axis, but also an angular momentum $I_{xy}\omega_x$ about y-axis and an angular momentum $I_{xz}\omega_x$ about z-axis, though it "doesn't rotate about y-axis or z-axis". Most of the beginners find this a puzzling paradox. In the article The Puzzle of Gyroscopic Motion[2], I pointed that ROTATION about a certain axis does not do necessarily mean CIRCLING that axis, but means variation of azimuth relative to that axis. Since a rigid body is nothing but a collection of particles, let us consider a particle circling x-axis (Fig. 4a). It is easy to see that the azimuth (relative to y-axis) of its projection on xz plane (Fig. 4b) is changing. In others words, it does

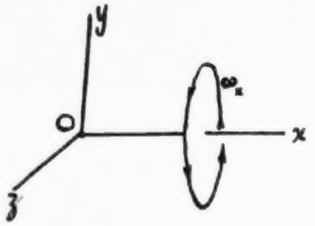

Fig. 4a

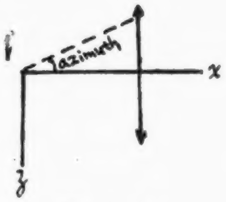

Fig. 4b

rotate about y-axis though it doesn't circle y-axis. Thus, it is no wonder that it possesses angular momentum about y-axis. The same may be said as regards z-axis.

As another example, in most textbooks, the Coriolis acceleration is deduced as follows:

$$\vec{V} = \vec{V}' + \vec{\omega} \times \vec{r}$$

(quantities with a prime refer to rotating frame of reference, these whithout prime refer to inertial frame.)

$$\begin{aligned}\vec{a} &= (\vec{a}' + \dot{\vec{\omega}} \times \vec{r} + \vec{\omega} \times \vec{v}') + \vec{\omega} \times \vec{v} \\ &= \vec{a}' + \dot{\vec{\omega}} \times \vec{r} + 2\vec{\omega} \times \vec{v}' + \vec{\omega} \times (\vec{\omega} \times \vec{r});\end{aligned}$$

the term $2\vec{\omega} \times \vec{v}'$ is called Coriolis acceleration. This is mathematics, looks rather abstract. In the article Mathematics Is Not to Be Blamed [3]; I gave a vector diagram illustrating the physical origin of Coriolis acceleration. The absolute motion of the particle may be resolved into two parts, viz., the motion as if it were carried by the rotating frame and its motion relative to this frame. The velocity of the former changes because of the latter motion; the v velocity of the latter changes because of the former motion. Such is the origin of coriolis acceleration.

SUMMARY Classroom lectures are not doomed to be MAN-TANG-GUAN (compressing knowledge into students all the while). They have a merit over self-taught system: deep physical insight.

1 Talks at International Symposium on Physics Education, Beijing, 1982. Also published in University Physics, no. 1, p.25 (1984). University Physics is a monthly periodical dedicated to physics teaching supervised by Chinese Physical Society. Articles in university Physics are written in Chinese.

2 University Physics, no.3, p3 (1985)

3 Proceedings of GIREP 1984, Utrecht, the netherlands. Also published in University Physics. no.1, p1 (1986)

COMMUNITY-BASED PHYSICS EDUCATION

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Abstract

The paper presents a research undertaken by the Physics Workgroup of the Institute of Science and Mathematics Education Development, University of the Philippines, on the feasibility of community-based physics teaching in grade 10 (age 16). Involved in the study were five schools: two in a farming community, two in a fishing community, and one in an urban community.

Some physics-related community projects of students are described. Differences in student performance in unit tests between a class doing physics-related community projects and a comparable class without community projects are noted. Attitudes of teachers and students towards the community-based approach are presented. Comparisons across communities are made. Problems and difficulties encountered are given.

SELF-STUDY LAB —— A TRIAL TO IMPROVE THE LINKS IN OUR PHYSICS EDUCATION

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In recent years, much attention has been devoted by our colleagues in China to the development of creative power and spirit of bringing forth new ideas in our physics students.

It is a longstanding tradition in our physics education to lay stress on prepairing a solid foundation for our students, which is an indispensable prerequisite for doing creative work. In these years, the level of our students' knowledge has been markedly raised. However, it is also widely concerned about that not enough attention is paid to efforts to make the students more adaptive in their study and to cultivate their ability to analyse and solve concrete problems independently. Consequently, measures have been taken to enlighten students' load in their compulsory studies as well as to make improvements in the links of our teaching —— such as setting up outside reading seminars, encouraging students to write essays about what they have read, giving more emphais on laboratory courses to experiments that require students' own planning, etc. The Self-study Lab is what we have introduced into our first two years' education as an effort to attain this goal. It seems to wrok with some success.

The Self-study Lab has two forms, developed from different origins, though now quite interfused in many aspects. One of them is related to lecture-class demonstration, in fact originally taken as a means to extend the classroom demonstrations. Students, paired into groups, are given sets of apparatuses to do their own experiments and study what they are interested in. The other one is the so called "Project group", each with two or three students. They choose their project from our list of topics, set up equipments and work on it till they get the proposed results, usually in about one term. The essential spirit of these forms are in common, i.e., to create for our students the opportunity of doing experimental work with greater flexibility, in order to foster their ability to analyze and solve problems on their own.

1. Demonstration-Self-study Lab.

In our country, General Physics and General Physics Laboratory are mutually independent courses. In General Physics lecture classes, demonstration plays a unique role in connecting theory with practice. Students enjoy them very much. What seems to be unsatisfactory is the limitation of time, just a few minutes amidst the proceeding of lectures, with little opportunity for students to operate. Many of them, after seeing an interesting demonstration in the class, wish to go deeper into it by observing more closely and operating by themselves, or even study further some related problems. Mindful of this, we set up a series of demonstrations in coordination with lecture contents (e.g. electrostatics, electromagnetic induction, vibrations and waves, geometrical optics and wave optics) and admitted students interested in them to come in spare time and do the experiments. We encouraged them observe the phenomena, raise questions and tried to answer them with the knowledge they learned in the lectures. In the experiments on electrostatics, they were excited at experiencing a voltage of tens of thousand volts carried on their own bodies, without uncomfortable feeling and danger of suffering a shock. Students are usually much more impressed with a phenomena when they have observed, tested and made efforts to explain them. For instance, we let them do adjustments on equipments and make observations after lectures on such topics as Combination of Mechanical Oscillations, Influence of Slit-widths on Interference and Diffraction Fringes. Students can see much richer phenomena and grasp deeper the contents than when simply listening to lectures and doing exercises.

Last semester, our General physics Lab started a similar program, opening their optional experiments on two evenings weekly. Students registered beforehand are admitted to do the experiments without compulsory requirements and are encouraged to explore into the subject and exercise their lab skills in their own way.

2. Project groups.

We began to organize the Project groups in 1981 in our Optics Lab. Students came to work on their projects one afternoon every week. Since then we have run it for six terms, with 6 or 7 groups each term, about 100 students having participated in. The students admitted are among the best ones of the class and we demand them with a higher standard. Some of the project topics come out of our own research work, and others are involved with new experiments planned to be set up in our General Physics Lab, both of some practical value to us. In accomplishing such a work, the student gains the experience of taking part in the whole course of a research project.

After choosing the topic, students usually spend 2 to 3 weeks reading reference materials (we assign them 5 or 6 papers, 1 or 2 of which in foreign language) and then discuss with us on the plan of the work and make the necessary preparations. Most of the equipments needed are collected from our stock, but have to be installed, adjusted and calibrated, and sometimes some of the apparatuses are to be made or repaired by themselves. When these are ready, they get on with the experiment, do the observations, measurements and analysis of data, and write the report on the final results at the end. In the course of their work, students meet with different kinds of difficulties that they have to tackle independently. We work actively in face of these and keep on their enthusiasm from beginning to end. Their results are usually good and some quite outstanding. The report on "Measurement of the angle of divergence of multi-mode He-Ne laser beam" was presented in the nation-wide conference of the Society of Metrology of China. The works on ultrasonic diffraction, measurement of piezoelectric coefficient of piezoelectric ceramic with Michelson interferometer etc. are transferred into General Physics Lab experiments after further refined by the Lab faculty. Of course, they enhance their ability to do independent work.

Since the starting of Optics Project groups in Sophomore students, similar groups are organized by the Mechanics and Heat sections of General Physics Lab and the Demonstrations Lab for the Freshmen, which also proved to be successful. The only problem was that, as Self-study experiments were carried out as an extra- curricular activity, we can only absorb the top students but not those from a wider circle, because they had already heavy load of study. In the Autumn Semester last year, our Department decided to recognize Self-study Lab work as an optional course. 2 credits are given to the student who works 36-40 hrs in one term and hands in the final report approved by the instructor. This transformed the position of Self-study Lab work from something of a sparetime activity to a part of the curriculum and is indeed advantageous to its development. As the average Freshmen have often less acquaintance with lab practice and ability of independent work, the demands should not be so high as in the Sophomore section. But the essential aims and the general procedures are about the same. We give them some guidance in drafting their plans and setting up the equipments. The topics of experiments are more related to the lecture contents, such as the verification of the energy relations in harmonic oscillations, measurement of natural frequency of tuning forks, etc. Some of these can be used as lecture demonstrations when completed. It seems that we could recruit more Freshmen to Self-study lab work in the future if we maintain adequate levels of demands and guidance.

Summarizing what has been done in the Self-study Lab in these years, we can see that it is effective in the following aspects.

1. It enhances the students' initiative of enquiring.

Students come to join our Lab often with a desire of acquiring knowledge or skill. As they proceed on with their work, they find even greater delight in probing into something unknown, raising and solving problems with no ready answers. In our Optics lab, one of the favorite projects is the diffraction of laser beams, in which the students found many interesting problems that they liked to deal with with their theoretical knowledge. What we do is to let them feel also the importance of going further with their experimental work. This project has been done six times; each time students found new problems to probe into in their experiment. Another typical case is in the project "Photoelectric Effect", in which we gave the students the task of improving an experiment of this title in our General Physics Lab. By then we knew it did not give satisfactory results but had not yet started to track out where the problem was. The Project group did the "diagnosis" through experimenting and anlysing with theory and found out that the trouble was in the phototube which was in fact gas filled.

The freshmen who were for the first time admitted to our lab were highly enthusiastic with their experimental work. We afforded the group that took to verify the energy relation in simple harmonic motion a set of airtrack with accessories, but did not tell them the procedures. At first they were quite at a loss what to do. But after a period of groping and practicing, they soon got the idea that the key of the work is the measurement of instantaneous velocity. After trying four different approaches, they finally succeeded in finding out a method of measurement that worked. The group that studied the influence of electric field of water jet flow tested the interaction by applying the field with different arrangements, and to their delight, found out the causes of various phenomena in jet flow and got good results in verifing their inferences with further experiments.

Undergraduate students of the first two years are in an age with a strong will of enquiring and creating. Generally speaking, they are not yet competent to do research work by conventional standards. But it is important for us to care for, to support and develop their initiation, to suggest to them subjects appropriate for them to work with and to supply them with the necessary equipments, bringing the potentiality of their creative power into full play and strengthening it through their practice in experimental work. We have seen that the Self-study Lab has indeed provided us with such an opportunity.

2. It promotes the combination of theory with practice.

In our Freshman section, as the experiments are related with the contents of lecture courses, students find many circumstances in which they must apply their knowledge from theoretical and experimental studies in a combined way. Sometimes we give them some guidance to promote this. For the group working on electrostatics, we gave them 20 interrelated questions which guided them to study the principles and the phenomena through experimenting. They commented on these as having the effect of widening their views and livening their thinking, deepening their understanding of electrostatics as well as enhancing their ability in practical work.

In the Sophomore section, the projects demand higher of students the ability of applying their theoretical knowledge to practical problems, e.g. starting to handle a project with an analysis from the angle of physics, finding out the primary factor in complicated phenomena and trying to explain them with simple models. These are just what people always do in practical work and should certainly be considered as basic skills in the training of our stduents. In fact, it is much more difficult to develop students' capacity in these respects than to teach them solve textbook problems. But unfortunately, it is often somewhat neglected in our education. The Self-study Lab could have some effect on making up this deficiency.

Students in project groups often have great interest in the discussion of theoretical problems and underestimate the importance of experimental work and the extent of its difficulties. Owing to lack of experience in establishing equipments, in many cases, they expect us to provide them ready-made apparatuses to do the measurements directly. It seems important to devote attention to their training in this respect. In the Sophomore section, we give them several weeks' training in welding techniques. We also pay attention to the guidance of their work in establishing equipments. They usually made good progress when accomplishing their work. In Optics lab, they have set up more than ten laser power-packs and and measurement amplifiers and repaired many other instruments. Some of them made good improvements in the design of instruments. That of the ultrasound generator and of the automatic device on a monochromator are among the best.

Generally speaking, through their experience in our lab, students pay greater attention to experimental work and realize that, to do creative work, not only brain racking is needed, but also are the well-trained basic laboratory skills and the rigorous style of study in experimental work. Some of them were so highly interested in their experiments that they even continued their work in the summer vacation under the hot and close conditions of our lab.

3. It improves the students' ability to analyze and solve problems independently.

The course of students' work in our lab is under the care of the instructor from the beginning to the end. In the first several weeks, we usually spend well over one half of our time to make the preparations ready and help the students get on the right track. But we always give them a free hand to go on with the work by their own whenever it is possible. They got much improvement in their ability of independent thinking and work along with the proceeding of the experiments. The tasks for some of the groups, such as those on piezoelectric ceramics, characteristics of optical fibers etc. are rather difficult ones, in consideration of their background. But they accomplished them in a shorter span of time and with better results than we expected. The group on the measurement of diverging angles of multi-mode laser beams was originally engaged in another project, which they were forced to give up as the necessary equipments were not available, and transferred to this new work in a situation pressed for time. But they made a good start and finished it with successful results in only two months. They owed this to their discontinued work, which was indeed not worthless. Some of the students with remarkable achievements in our lab are not among the best ones of the class in their examination records. They showed their capacity in their independent work.

In our Freshman section, generally we give students more guidance but also let them try to do all things within the reach of their capacity. Though we have made tentative plans for the work, we do not show them to the students but require them to arrange by themselves and always encourage them to test their own ideas, even if they do not seem feasible at first sight. Many of them got very good results by their own thinking and work. The group on optical communication made various trials to improve the design of the light path and succeeded after many failures to communicate with a tiny bulb for a distance of 30 meters. The group on the demonstration of rotating frame of reference designed an apparatus for the measurement of inertial centrifugal forces, in which no frictional forces are involved, whereby accuracy is increased.

In Self-study Lab activities, when students go on with their experimental work, they are challenged by the necessity of combining the knowledge and skills they learned in different courses and applying them to the exploring of new problems. This results in advancing their ability to do independent work, with an effect not usually having in other links in our procedure of physics education.

The establishment of separate courses is the convention of school education. No doubt, taking courses systematically is the most efficient way for students to grasp their essential contents. On the other hand, when students leave school and go into work, they seldom find themselves in a position that they can rely on knowledge ready at hand. When they are given the tasks of investigating a subject, drawing up a plan, setting up equipments and going on with an experiment etc., they meet with many problems which they have not experienced at school. In solving these problems, what is needed is still the knowledge they learned at school, but in a context quite unfamiliar to them. This is often a situation difficult for them to adapt to. In our opinion, though the basic training in our individual courses is quite satisfactory, there are still deficiencies in their coordination. We have not paid enough attention to the students' practice in applying these separate branches of knowledge comprehensively. In our undergraduate curriculum, the Senior dissertation seems to be the chief form of training that meets this purpose. Students highly evaluate what they have benefited by their experience in this training of applying what they learned in their four years' study. The deficiency is that this is only done in the final stage of undergraduate education. An ability can only be developed through step by step accumulation. For the development of students' ability of applying their knowledge comprehensively and that of exploring, researching and working independently, it seems preferable to distribute the training to all the four years of our education, in coordination with the lecture and laboratory courses, forming a stepwise spiraling structure in advancing this ability.

It is possible to do this by preserving the present structure of our curriculum, supplanting it with activities like Self-study lab work with optional course credits. The role it plays in concert with the required fundamental courses, will enable us to keep up our students' merits of having a solid foundation and add something more to make them more adaptive in their study.

Our Self-study Lab is still in a stage of infancy. We need more practice and experimenting, and follow up surveys to evaluate its effects on the students' development. More support on manpower of staff and on equipments, especially in regard to the arrangement of the teaching load of instructors is expected. It is also most desirable for us to learn the experiences in laboratory teaching rennovations from our colleagues at home and abroad —— an example is that of Prof. J.G.King of M.I.T., that we benefited through his introduction during his visit to our Department last year. We are ready to devote efforts in further improvements of our lab.

Latent Abilities Needed for Physicists

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The lecture of physics should be started so that it attracts the interest of students, and it is also important to satisfy their desire during the lecture.

The result of a factor analysis for research workers shows that the ability of expression is related to all other human abilities.

A scientific analysis has been made on the course of graduates of physics, and it has become clear that those who have originality or ability of expression are suited for research works, but that those superior in judgement or calculation for technical works. The analysis has also shown that the ability of expression is needed for those holding administrative positions for both of these works.

Without integrating one's sensitivity, understanding and practice, one cannot succeed in the field of physics, nor education and research in physics are fully accomplished.

1. Physics as a Subject of Thought

Physics is one of the typical natural sciences. It leads us to a truth by any means unless we have contradictions in the observation of phenomena and in the process of thought and operation. Physics is not simple, so that it is important to develop such a method of lecture that enables the students to get a good understanding of the contents.

2. Research and Education

2.1. Research

Research has a purpose to solve the problems in the undeveloped field. It is indispensable for a prominent research worker to have an ability to recognize phenomena by intuition.

2.2. Education

The purpose of education is to teach the well-developed system of knowledges. The relation between education and research is given in Fig.1. A prominent educator must be able to explain advanced matters in a simple manner and also to prepare teaching materials containing simple explanations [1, 2].

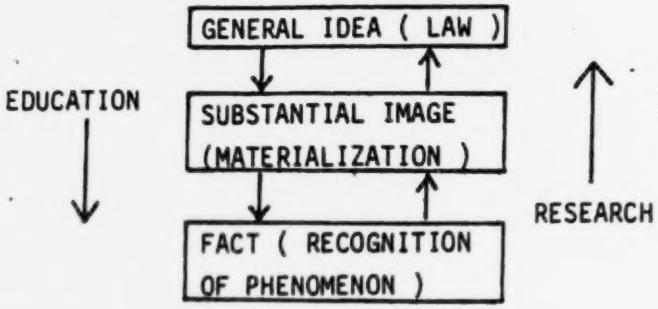
GENERAL IDEA (LAW)
EDUCATION
SUBSTANTIAL IMAGE (MATERIALIZATION)
RESEARCH
FACT (RECOGNITION OF PHENOMENON)

Fig. 1. Relation between education and research.

3. Planning for Lecture

The brain does not respond unless the subject attracts interest. One cannot feel interested in the phenomenon which one cannot understand [3]. The next two points, therefore, are very important in the planning for lecture :

1) To start the lecture in such amanner that the students feel interested in a theme. To end it with sufficient satisfaction of their interest. These are necessary for the formation of scientific idea of the subject.

2) To adopt the method of lecture which can make all students recognize scientific idea and law.

4. How to Learn Sciences

The substantial image is indispensable for the formation of scientific idea [3,4], and the idea becomes of one's own only through the integration of sensitivity, understanding and practice especially in physics. The understanding works only with the help of recognition based on a vivid intuition, which arises from the cooperation of the brain and the making as a physicist.

5. Estimation of Progress in Learning

5.1. Method to estimate the effect of education

Estimation of education
- degree of progress in learning (estimation of academic ability by examination)
- learning system and content of lecture

The degree of progress in learning has been estimated by the result of examination which the teacher of each subject prepared from an indipendent standpoint. Nowadays improvements are made on this subjective method of estimation, and there appears a tendency to estimate the result of education from various viewpoints.

5.2. Many-dimensional estimation of degree of progress in learning

The degree of progress in learning should be estimated especially concerning the following points :

1) Understanding of fundamental knowledges.
2) Ability to solve practical problems using knowledges and formulae.
3) Ability of expression.

5.3. Object of estimation

The total ability of an individual can be estimated by testing the following factors [6] :

1) Ability of calculation.
2) Ability of accumulating knowledges.
3) Ability of concentration.
4) Ability of management.
5) Creative power.
6) Judgement.
7) Ability of expression.

5.4. Latent ability estimation by factor analysis

A factor analysis has been made on what kind of ability is wanted for various sorts of occupation or classes in science and engineering. The results have been compared with achievements of individuals to give Table 1. This research has shown that the ability of expression is the most essential and most deeply related to another kinds of abilities.

Table 1. Abilities wanted for sorts of occupation and classes.

ORDER OF IMPORTANCE	RESEARCH AND DEVELOPMENT		ENGINEERING	
	ADMINISTRATIVE	NON-ADMINISTRATIVE	ADMINISTRATIVE	NON-ADMINISTRATIVE
1	EXPRESSION	EXPRESSION	EXPRESSION	JUDGEMENT
2	ORIGINALITY	ORIGINALITY	JUDGEMENT	CALCULATION

6. Application of Latent Ability Estimation — Course Selection of Graduates in Science and Engineering

6.1. Ability needed for learning

The ability of accumulating knowledges is needed for learning at lower classes, and that of understanding and thought at higher classes. Figure 2 shows the abilities which are the most necessary for learning at various stages of Japanese education system. These are averaged for five subjects (English, math, Japanese, civics and science), and it is needless to say that the ability of understanding is most needed in physics.

6.2. Course selection of graduates in science and engineering

Generally speaking, graduates of today are short of not only general calture and ability of writing but also common sense for human relation. We should call it into question that they are lacking in ability of expression and sence of cooperation [6,7,8], because these are essential in science and engineering. The graduates in this field select the course according to latent abilities as shown in Fig.3.

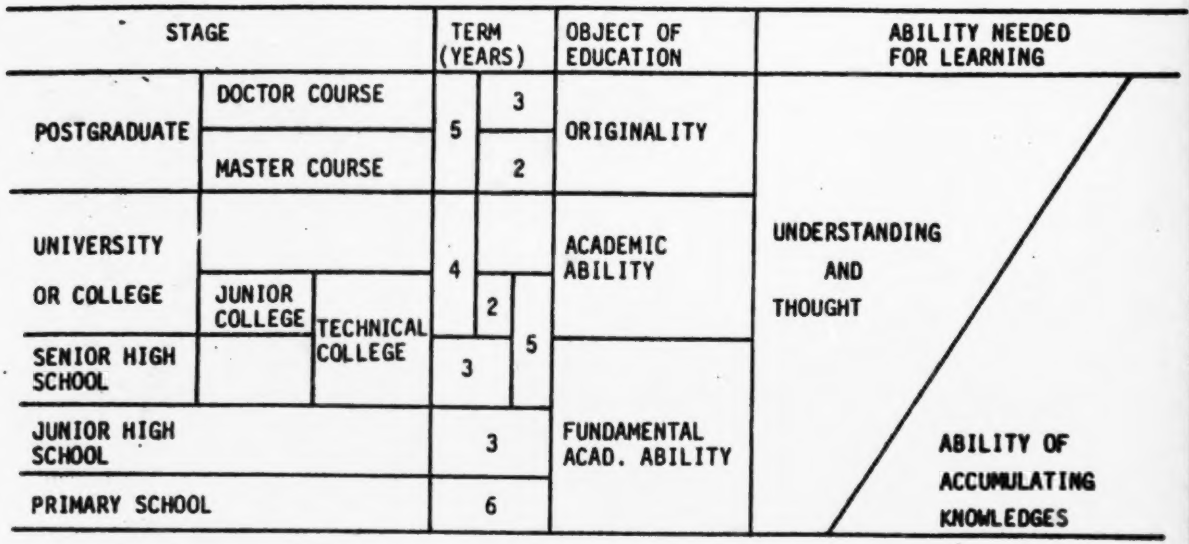
STAGE
TERM (YEARS)
OBJECT OF EDUCATION
ABILITY NEEDED FOR LEARNING
POSTGRADUATE
DOCTOR COURSE
MASTER COURSE
5
3
2
ORIGINALITY
UNIVERSITY OR COLLEGE
JUNIOR COLLEGE
TECHNICAL COLLEGE
4
2
5
ACADEMIC ABILITY
UNDERSTANDING AND THOUGHT
SENIOR HIGH SCHOOL
3
JUNIOR HIGH SCHOOL
3
FUNDAMENTAL ACAD. ABILITY
PRIMARY SCHOOL
6
ABILITY OF ACCUMULATING KNOWLEDGES

Fig. 2. Abilities needed for learning at various stages of Japanese education system.

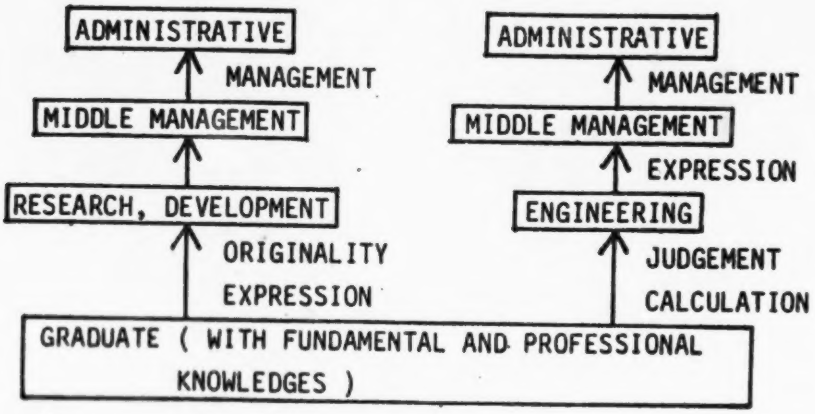
ADMINISTRATIVE
MANAGEMENT
MIDDLE MANAGEMENT
RESEARCH, DEVELOPMENT
ORIGINALITY
EXPRESSION
ADMINISTRATIVE
MANAGEMENT
MIDDLE MANAGEMENT
EXPRESSION
ENGINEERING
JUDGEMENT
CALCULATION
GRADUATE (WITH FUNDAMENTAL AND PROFESSIONAL KNOWLEDGES)

Fig. 3. Course selection of graduates in science and engineering according to latent abilities.

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A TENTATIVE STUDY OF THE IMPROVEMENT ON THE EDUCATION OF THE FUNDAMENTAL PHYSICS IN POLYTECHNIC INSTITUTES OF CHINA

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One of the main problems confronting the education of the fundamental physics in polytechnic institutes of China of present is the contradiction between the limited class hours (120-140) and the growing subject matter, teaching in this case would necessarily lead to the fast advancement, the spoon-feeding way and to the "indigestion", and, therefore, would unable to increase the students' ability to analyse and solve problems, if all-round lectures were delivered. How to enhance effectiveness of physics teaching, how to train problem-solving ability of the students are two of the problems discussed extensively and heatedly among collegiate physics teachers these years. They may probably be common problems perplexing physics educational circles in other land too.

In this paper some points of view about improvement on the teaching of physics based on my personal experience and survey are presented in order for us colleagues to deliberate them over.

Four main points are summorized as follows:

1. Make further sure of the task of the fundamental physics course and take suitable steps in teaching programs.

In order to improve the teaching quality of fundamental physics in the polytechnic institutes, the primary job is to make further sure of the task of the course. In my view, the main task include the following two aspects: first, to pass on knowledge of physics, i.e. to teach fundamental phenomena, concepts, laws in physics, so as to lay a solid foundation for subsequent studies; second, to foster the ability for physical thought, i.e. to foster the ability for physical thought, i.e. to foster the ability to draw physical nature from a variety of physical phenomena and to investigate problems with physical models, and the ability to analyse physical processes with the help of proper mathematics, at the same time, an emphasis is also put on the spirit of inspiring the student to explore the unknown world. The latter aspect is laid special stress on in modern educational science, and is called intelligence development.

Of course, these two aspects are interdependant. The training of the ability for physical thought, or generally, the training of intellegence resides in the teaching of knowledge, and the teaching in turn permeates that of intellegence. I would, however, place my emphasis on the second aspect of the task. This is because that knowledge transference is not lost sight of in general, but the intellegence training is liable to be ignored or quite different for different persons. As is well known that physics deals with the most general and fundamental laws of matter and motion, that physics is the foundation and foreruner of technology and other sciences, that physics is the pioneer going before the modern science. In the teaching of physics characterized by all this, to enhance the students' quality, it is undoubtedly important that an attention be paid to train the ability for physical thinking.

On the other hand, science and technology is nowadays expanding by leaps and bounds, the knowledge of physics that can be considered as fundamental is ever-increasing too. In such a case, if we adhere to the transference of more complete, ever rudimentary knowledge, the teaching tempo must necessarily be quickened, and the student may not well digest what they have learnt and be at a loss to solve a problem. Accordingly, it is often said among teachers of physics in our country that "do we provide the student with a pile of hunting bags or a gun?" Obviously, those in the bags will go bad and our knowledge will become aging, so it is only reliable to grasp the gun and methodology.

If educational circles of physics in our country have a common understanding in this respect, then it is able to get rid of the belief that "as a basic course, it must be served to lay an overall foundation", and to selectively lecture fundamental physics, for instance, mechanics, electricity and magnetism, and optics, may be treated as required parts of physics and may be given deeper lecture with an attention being paid to traing the ability, while the rest parts can be taken to be an elective or self-taught. In this respect, we can draw on the experence of Japanese institutes of science and technology.

2. Provide the student with a variety of teaching materials adapting to the development in physics and the modern theory of pedagogy.

A testbook is different from a scientific monograph. The former is not only a collection of systematic knowledge but also the enbodiment of a specific educational thought and the crystallization of the collective wisdom of teachers as well. During the teaching, a definite testbook or reference books are always designated, so that the teaching material is the one on which the teaching is mainly based, and an important source from which the student sucks in knowledge. The quality of textbook inevitably has notable impact upon the student's mastering of the subject and his intellegence development.

A number of good testbook well-known all over the world and praised highly by numberous teachers and students. Some of them are as follows: Halliday and Resnick, Physics, Berkeley Physics Course, The Feynman Lecture on Physics, Kinbara, Fundamental Physics. They have been translated into Chinese. Most of the textbooks of physics adopted in our colleges are written by us Chinese aothors, and published after "the Great Cultural Revolution" and advanced and organized by the Editional Board of Textbooks used in the polytechnic colleges. This new lot of textbooks have been playing an important part in ensuring teaching quality of physics. But most of the physics teachers hold that these textbooks are somewhat of the same structure and lag behind the world advanced level. The over-all layout and illustrations are dull and monotonous. The author has made a comparative study of the range of knowledge with illustrations between the General Physics written by Cheng Shouzhu and Jiang Zhiyong and T. Kinbara "Fundamental Physics" and M. Alonso & E.J.Fin" "Fundamental Universit Physics", and discovered the former offering a smaller converage in heat and statistical physics, mehcanics, quantum physics.

In order to improve on the teaching of physics in polytechnic institutes, we should strive hard for providing better teaching materials. According to the author's teaching experience for many years in college, in view of the role of physics teaching mentioned above and the general trend of modern physics, he maintains that a number of new textbooks having new characteristics should be supplied for the student. The considerable characteristics are as follows:

a. a proper allocation of materials of classical and modern physics and interweaving as an organic whole;

b. adding to the traditional longitudinal structure of the subject matter, namely, the sequential approach of mechanics, heat, electricity and magnetism, light and quantum physics, the modern transverse connecting links such as the material object and the field, macroscopic laws and their microscopic nature, the wave and statistical nature of physical processes.

Such teaching materials gives rise to additional educational effectiveness and confirms to the systematological principle that the function of the whole, E_W, is greater than the sum of the functions of its seperate parts, $\sum E_{sp}$, and

$$E_W = \sum E_{sp} + E_g$$

E_g being the function generated by the orfanizaition of the seperate parts into a whole.

c. being more copious in contents and up to higher scientific standard.

Although that to be lectured should be limited, the contents of textbooks should be richer and the scientific standard should be higher. This is a paradox. Such a design of textbooks has two purpose in mind, to develop the student's thinking ability and to raise the student's self-taight ability.

d. being suitable to students of different specialities. Many new specialities such as humanistic-physical (economic administration, etc.) and science-technology (applied mechancis, applied mathematics, etc.) are being set up nowadays in Chinese polytechnic institutes. The former require a wide range of physical knowledge and a good command of the methodology of physics rather than theoretical calculating ability, while the latter demand more advanced physics than the traditional specialities. Various textbooks should be published to meet such demands.

3. The classroom lecturing should adapt elicitation method, embody conscious activity and correctly handle the relation between teacher, students and teaching facilities.

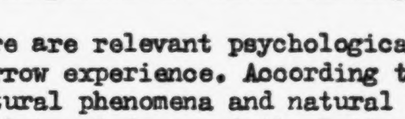
There are generally classroom lecturing, class in problemsolving or seminar, laboratory experiment, tutoring after class, etc. in physics education in a chinese college, and there is sometimes demonstration in lecturing. In this time of rapid growth of science and technology, audio-visiuall means and computerized aids are lots. T.V. sets and videotapes may be used to aid instruction and subject matter may be programmed, students can utilize a computer to get a clear understanding of a concept, and to clear up a knotty problem. There is no doubt that these facilities make positive impact on the teaching effectiveness, especially when the audience is large and the teachers' solicitude is not sufficient. But the theory of pedagogy holds that the teacher should always play the leading role in the process of education and it can not be replaced by any modernized teaching means whatever. And the classroom lecturing is obviously the most important link among all of the activities of instruction. Therefore the author belives that to enhance the classroom lecturing quality is the key to the teaching effectiveness of the physics course.

We stand always opposed to "the spoon-feeding way of teaching" in our fundamental physics teaching. The so-called "the spoon-feeding way of teaching "means continually flooding the class with concept-introducing, formula-deriving and conclusion-jumping, thus making students busy taking notes, and have no time to think and digest. We advocate elicitation method in teaching, explaining clearly the cause and effect of a concept, approaching a theory from various angles and analysing and elucidating significance of a conclusion.

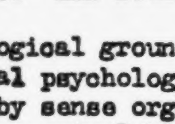
Elicitation method requires lecturing at a leisurely pace, but the limited class hours and attention to each and every aspect of a matter in teaching makes impossible to do so. In order to implement the teaching principle of elicitation, we must lay stress upon some main parts of physics course. Vividness in teaching is an important aspect of elicitation. By vividness is meant lively description, obvious demonstration, profound analysis in simple terms of a physical problem, to make the student understand and deeply impressed. For instance, in studing about difraction and interference of light, discussion of questions over demonstration with laser as light source is much better than such experiment by students after class. In addition, the author holds that emphasis should be put on consciously active instruction, that is to say, when teaching, the teacher should not pass on viewpoints, indroduce facts and theories coldly and indifferently, but explain physical problems along with his own viewpoints and understanding to appeal to his students.

There are relevant psychological and pedagogical grounds above personal narrow experience. According to educational psychology, men understand natural phenomena and natural laws first by sense organs' direct perceptual knowledge, and the latter leaps to conceptual knowledge later on. Vividness in teaching is advantageous to giving free play to these sense organs in the understanding of natural phenomena. Moreover, educational psychology stresses students' interest as the direct impetus of their studying. Vividness, elivitation and conscious activity are, of course, beneficial to rous the students' interest in studing physics.

Lively dialogue, serious discussion and ideological interchang contribute much to the mobilizing the students' studying enthusiasm and inspiring their thinking, as proved by experience. Such parts can not be replaced by any advanced computer or any audiovisual aids. Under the circumstances that lots of new devices such as videotapes, T.V. sets and computers are gradually being introduced into the process of education, it is worth while probing into the problem how to correctly handle the relationship between the teacher, the students and the machanics. The author believes that the three are in a triangular relation to each other (fig. a) instead of a linear relation (fig. b).



(a)



(b)

In audio-visual instruction and CAI, teacher's chief task if to prepare telefilm and programming, he is directly related to machines, and he is clearly in a linear relation to the other two. Teacher and students lack direct interchange of information, thus doing harm to the education of students. A machine may answer and explain questions instead of a teacher, but it is a thoughtful, learned, and nodle-minded teacher that the enlightenment of thinking chiefly rest on.

4. Pay more attention to an introduction for some historical facts of physics to the course.

A number of departments and specialities in Chinese colleges often require to increase the contents of modern physics. Emphasis on modern physics in teaching is doubtlessly correct, but from a broader goal of physics education, it is necessary to keep a proper eye on history of physics. The author feels that spicing lecturing and teaching materials with histotical facts may be of inspiration.

Introduction of some historical materials of physics has the following advantages, as proved by experience.

a. To help the students understand the relation of the growth and development of physics to the social production. That is to say, the demand of social life and social production has pushed physics forward, and the development and achievements of physics has in turn promoted the social production.

There are many example in this respect. For instance, we may introduce the background of the formulation of the first law of thermodynamics and the guiding role of the second law of thermodynamics in improving the efficiency of the heat engine and promoting social production, etc. It is even more interesting if we further illustrate that the theoretical researches in thermodynamics and the advancement of Carnot's principle at that time were not in England, the motherland of the inventors of the heat engine, Newcomen and Watt, but in France, where there were a number of engineers well-cultivated in theory. We thus shed light on the importance of theoretical accomplishments of physicists in the opeening up the path for the development of physics other than the motive force of objective needs.

b. To enable the students to comprehend the relation between the experimental and theoretical researches to realize that scientifical experiment are the very foundation of physics. Many vindications about the following general relation can be found in history of physics:

concept-presenting

experimenting —— —— theory establishing-

law-inducing

——theoretical prediction——experiment testfing

c. To arouse in the students the exploring consciousness of the material world and the devotion to the cause of science.

For example, when dealing with radioactivity, we can describe Curie Marie's work. By very simple apparatus and careful analysis bit by bit of 8 ton of pitchblende, she spent 8 long months of time to get only 1 gramme of pure radium. It was she who established the first institute of radiotherapy of cancer. She died of leukaemia due to long exposure to radioactivity.

Many physicists in history had ardent love for their undertakings and their people, undauntedly fought for the world's peace. Their deeds are good teaching material for educating young people.

Use may be made of oral account, poster paper, and special column of history in textbooks to introduce such facts.

Mention should be made here of the introducetion of the historic achievement of physics of the eastern nations other than those of the Western Europeans. There are numberous achievements of physics in China ancient history for us to cite. for example, in the Mocian Classics, a book of Mocius in the Spring and Autumn Period (300-400 B.C.), there is an accurate concept of force that 力(Li)者(zhe)形(xing)之(zhi)所(suo)以(yi)奋(fen)也(ye). 形(xing) is a body or an object. 所以(suo yi) means a cause or an origin. The original complex form of 奋(fen) is 奮, and the ancient type of 奮 is 奮, picturing a big bird to start to fly in a cropland, that is to say, to move from rest. In modern technical terms, the quotation means that force is the cause of change of sate of motion of an object. Another example, we Chinese came to form the concept of relativity of motion about 1600 years earlier than Galileo's discussion of relativity of motion. In ancient Chinese book, the Book of History, written in the last years of the Western Han Dynasty (about 100 B.C.), there is a statement that "Man is unaware of the constant motion of the earth much like he is unaware of the motion of a boat when sitting in it with all the windows closed."

There is no doubt that there are relevant historical materials in the other birthplaces of human civilization, such as India and Egypt. The author believes that proper introduction of such materials will make the student better realize the rise and growth of physics is closely related to the lives and productive activities of every nation in every land.

The above four points are the authors main opinions about the improvement on the education of the fundamental physics in Chinese polytechnic institute. Lastly, one more point which should be put emphasis on is that even today when lots of modern advanced teaching means have been developed, it remains very important to give full scope to the teacher's leading and enlightening role. Our ancient famous scholar Han Yu said in his article "On Teacher" that "The teacher is to propagate doctrines, teach, and to dispel doubts". According to my understanding of the matter, to teach is to pass on knowledge and skill, and to dispel doubts is to answer queries. For a physics teacher, is it suitable to interpret propagating doctrines as propagating doctrines of physics, passing on thoughts of physics, and cultivating thinking abilities? In a word, a teacher ought not to neglect such duties.

One thing should be explained away. Laboratory experiment is certainly a very important aspect for improvement on the quality of physics teaching. It is simply because of the limited space that the author completely omits treading it.
(The End)

MICROCOMPUTER SIMULATIONS OF A TWO-DIMENSIONAL IDEAL GAS: TWO MODELS FOR THE EVOLUTION OF SPEED DISTRIBUTION.

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Istituto di Fisica dell'Universitá-Via Archirafi 36-90123
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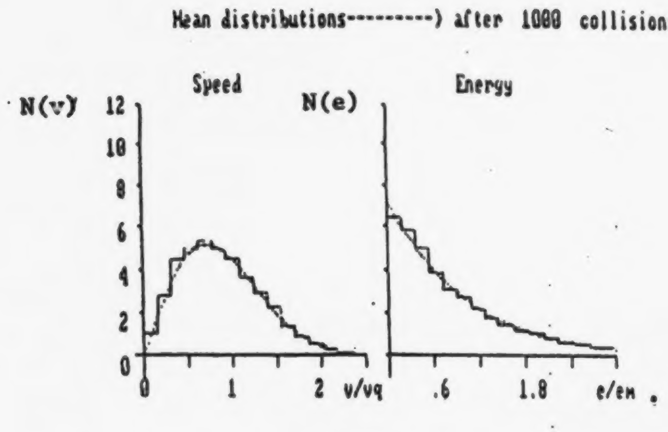
The undersanding of microscopic disordered motion in gases is difficult for most science students following typical introductory physics courses. In fact the analytical approach connecting the results of the kinetic theory of gases and the dynamical behaviour of simple systems (e.g. hard spheres colliding elastically) is not straightforward, and the Maxwell Boltzmann distribution function is usually presented as merely an empirical formula. Computer simulation of microscopic models can supply an interesting "experimental" support for physical theories, and a powerfull "mathematical microscope" for the analysis of the system microscopic behaviour.

We will describe two simple computer programs analysing two different models of ideal gas. The software has been developed in order to introduce, at high school and college levels, some concepts concerning the disordered motion in gases and the equilibrium properties. The programs describe two-dimensional systems of interacting particles and study the evolution of speed and energy distributions.

In the first model (M.L.Aiello-Nicosia and R.M.Sperandeo-Mineo, 1985) a system of hard core interacting particles is assumed, and a molecular dynamics method is used, in order to study the time evolution of speed and energy distributions in the framework of newtonian mechanics. The program solves numerically the equations of motion for a many bodied system and follows trajectories and velocities of the particles. Periodic boundary conditions are imposed, i.e. we imagine space to be filled by indefinite replications of the system. The walls of the box containing the particles are considered penetrable, and each particle leaving the box through a wall is caused to re-enter with unchanged velocity through the opposite wall. Consequently particles interact only with other particles. By starting from different initial conditions, the evolution of the speed distribution is analyzed in order to evidence as it approch a Maxwell-Boltzmann distribution.

Fig.1 shows the time average of the speed and energy distributions for a system of 25 identical particles, after 1000 iterparticle collisions. Particles were given the same initial velocity magnitude, with a random selection of the two direction cosines on the plane. The number density was equal to 0.1 with respect to close packing, and the initial position was randomly selected on a square box. Broken curves represent the theoretical Maxwell-Boltzmann distributions for two-dimensional systems.



v_q = root mean square velocity

e_m = mean energy per particle

Fig. 1

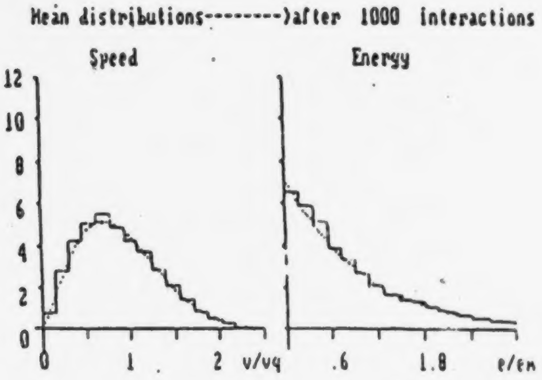
In the second model a random generator of binary interactions is constructed in order to account for disordered motion in gases. A system of N particles with their individual energies e_i is considered. The system is supposed isolated, and consequently the number of particles and the total energy $E = \Sigma e_i$ are conserved. Different microstate of the system are created on the base of the following rules :

-two particles i and j are random selected, and they are supposed to interact;

-the result of the interaction is a random change of the particle energies from e_i and e_j to e_i' and e_j'. This change is subject to the constraining equation: $e_i + e_j = e_i' + e_j'$.

A large number of repetitions of these two procedures results in a large number of microscopically different configurations the system can adopt. For each configuration the particle distribution of energy is calculated as well as the speed distribution (assuming that the particle energy is kinetic energy). Moreover the individual distributions are averaged on the ensemble of the different microscopic configurations (corresponding to the same macroscopic configuration), in order to obtain the equilibrium distributions.

Fig.2 shows the speed and energy distributions, averaged over 1000 different congigurations, for a system of 25 identical particles. They were given the same initial energy and they were left to interact on the base of the previously described rules.



v_q=root mean sqare velocity

e_m=mean energy per particle

Fig. 2

For both models the Boltzmann's constant H is calculated in order to study the system approach to equilibrium. Moreover for the equilibrium configurations, the time averages of the molecular dynamics method can be compared with the ensemble averages of the Monte-Carlo method.

Fig.3 compares the results of the two simulation models, and shows that they are both well fitted in order to describe the equilibrium energy and speed distributions of hard-core interacting systems.

Programs have been implemented on AppleII+ .

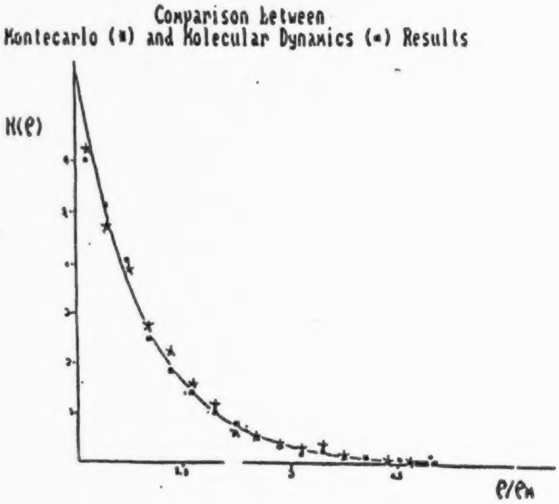


Fig. 3

References

M.L.Aiello-Nicosia and R.M.Sperandeo-Mineo "Computer simulation of a two-dimensional ideal gas:a simple molecuar dynamics method for theaching purposes.", Eur.J.Phys.(1985), 148-153, and included references.

Microcomputer Aided Audio-Visual Teaching System

Su Gang, Han Yu-xuan, Zhao Jiu-ming and Wang Wen-ming
Liaoning Normal University

Abstract

This paper presents the design and teaching application of a microcomputer-video player system. The system, in addition to independent use of either microcomputer or video-player, is designe to be an intelligent complex, which can produce splendid diagrams, sounds, image and word description under the microcomputer control and turns out to be an efficient teaching aid.

The design of the system consists of hardware structure and t interface circuit between the microcomputer and video player. Har ware equipment: The popular Apple-II plus microcomputer and video player 5030 (SONY) are employed; the interface circuit is designed with good use of internal interfaces and connectors for the simplification of circuit structure and an easy wide-spread use. For this purpose, a handy and flexible system management software is developed and a retrieval method of region-timing for tape-fil of video-player is designed. Computer aided simulation teaching a computer aided examination are also discussed in this paper. We regard computer-aided simulation teaching as a meaningful and promising field for CAI, and introduce our preliminary achievemen in this respect. In the section of computer aided examination, th

system software design targets, theory and system structure are discussed. The system can be used for either on computer examination (including scoring) or printing examination papers, which proves satisfactory in our work. The application procedure and examples are not presented due to the limited space of the paper.

The following is the full text:

Microcomputers have brought about many changes in modern teaching and arrested great attention of cultural and educational circl Among others, microcomputer have excellent functions, such as high speed calculation, plotting, huge imformation storage and quick refrieval, etc. It is believed that microcomputers can be applied i every teaching step.

I. Microcomputer Video-player Teaching System

Audio-Visual aids play an important role in teaching processes since teaching information is mostly obtained through vision and audition. Among them videotapes greatly contribute to modern teaching. In order to use video-player efficiently, we attempt to combin it with a microcomputer as a united microcomputer-video-player syst which is proved a success. It is of a new intelligent teaching syste making good use of a video-player in conjunction with a microcomput which is the main body controlling the video-player in information searching and displaying.

(A) Hardware

The hardware of the system includes the following main parts:

- Apple-II Plus microcomputer;
- 5030 Video-player by Sony (or the same functioning series);
- Interface circuit;

- CRT converse circuit.

The interface circuit is designed in accordance with the characteristic structures of microcomputer and video-player, with the best use of the inside interfaces and connectors. The microcomputer and video-player share the same CRT through the CRT converse circuit. Fig. 1 is the overall block diagram of the hardware.

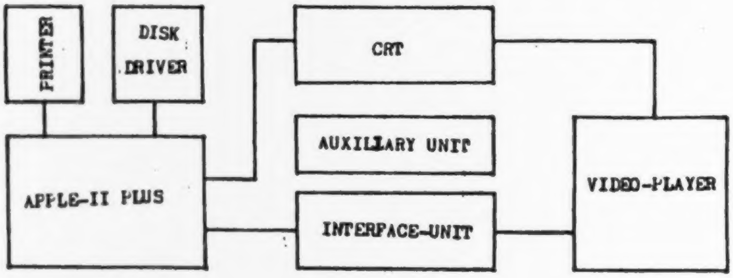


FIG.1 THE STRUCTURE OF THE MICROCOMPUTER-VIDEO-PLAYER SYSTEM

The interface circuit and plugboard chart of the peripheral adapter of the main panel of Appel-II are shown in Fig. 2. The interface circuit consists of address decoder circuit, data bus, selection circuit, versatile interface chip 6522 and output drive circuit. The select signal $\overline{CSZ}$ of chip 6522 is selected by $\overline{DEVICE}$, the 41st pin of Apple-II interface jack. A0, A1, A2, A3 are connecte to RS0, RS1, RS2 and RS3 on chip 6522 respectively to select 16 internal registers. Bus lines are connected conventionally. In order

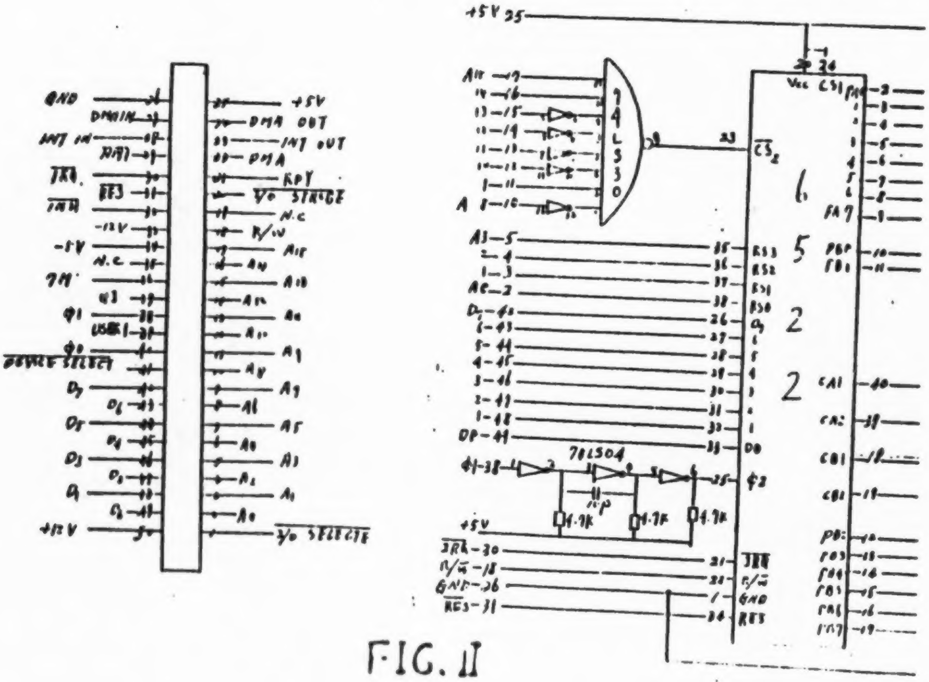

+5V 25
GND
DMA IN
INT IN
DMA OUT
INT OUT
DMA
RDY
I/O STROBE
N.C
R/W
-12V
-5V
N.C
7M
Φ1
Φ0
DEVICE SELECT
+12V
+5V
I/O SELECT
74LS30
6522
74LS04
4.7k
4.7k
4.7k
CS1
CS2
RS3
RS2
RS1
RS0
D0
Φ2
IRQ
R/W
GND
RES
PA0
PA7
PB0
PB1
CA1
CA2
CB1
CB2

FIG. II

to fit the interface voltage standard of the video-player the voltag converse chip MC1416 is put between the player and chip 6522. CA1, CA2 are for time connection.

CRT converse circuit is Video-change-switch controlled by microcomputer signals.

(B) Software

1. Tape message (audio and video) retrieval method.

For quick message retrieval, we make use of tape-region-timing First of all, we record the related subject matter to produce the sourse tape with the editor. According to the length of the courseware, the tape is divided into equal regions with an optimum plan to divide the tape into regions and numbered. There are blanks of 1 or 2 seconds (black) between the neighboring regions in order to stabilize the image and allow for the mechanical error for tape information searching (Fig. 3). The length of an item of the courseware may extend beyond one region, and a longer item can be recorded continuously in several regions. The best division of the courseware is that every item completely occupies relevant regions. In any case every item must begin with the very beginning of the region occupied by it (Fig. 3)

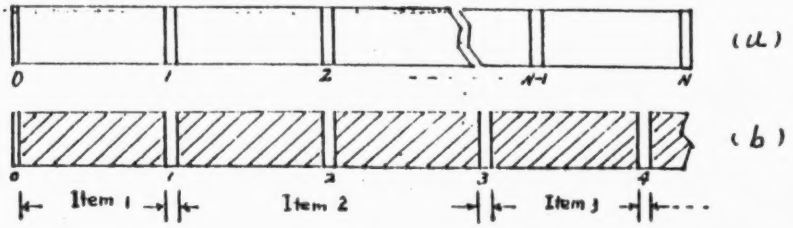


FIG.III TAPE DIVISIONS AND ITEMS

The servo system of the video-player guarantees the uniform angular speed of the tape wheel during fast forward moving (FFWD) and fast review (FRW). However, the tape speed is dependent on the thickness of the roll of tape on the wheel, the fact of which would thickness of the roll of tape on the wheel, the fact of which would cause trouble to the quick retrieval. To solve this difficulty, we made a FFWD and FRW time table (The FFWD and FRW time of any region determinded by actual measurments), and put it along with the courseware for use whenever necessary. (Table 1)

The registers and time counter for programming are:

- Aim location register GA: This register is for storing the sequential number of the beginning of the searched item.
- Present location register NA: for storing the sequential number of the location where the present item is.
- Time counter DL: for setting up every operating and waiting time required.

The judgement of the searching direction is as follows:

If $(GA-NA) > 0$, the computer finds out the time required from NA to GA from the FFWD time table, and set DL to perform FFwd timing

If $(GA-NA) < 0$, the computer goes through the FRW time table to find the time required from NA to GA, and set DL for FRW timing. When finished, NA is set as GA to complete the location conversion. Let the item length be L (in numbers of regions), the video display time is

$$DL = (\text{time for a region} \times L) \times \text{Constant}$$

where the constant is dependent on the time counter applied. When the displaying is completed, the present location is

$$NA = NA_{\text{previous}} + L$$

or $NA = GA + L$

thus accomplishing the location converting.

TABLE I FFW & FRW TIME TABLE

FRW

GA DL NA	0	1	2	3	---	N
0	0					
1		0		780		
2			0			
3				0		
⋮					0	
N						0

FFW

The number 780 in the table means that one second is taken for FFW from region 1 to region 3

2. Software arrangement

Applied software: The programmed teaching-models are dependen on teaching contents (we employed a branching programmed teaching model).

Audio-Visual Software: It provide the audio-visual content of teaching, such as lectures, demontrations, data and diagrams.

System management software: It conbines the applied software and audio-visual software as a unified courseware to control over the whole teaching system (Fig. 4)

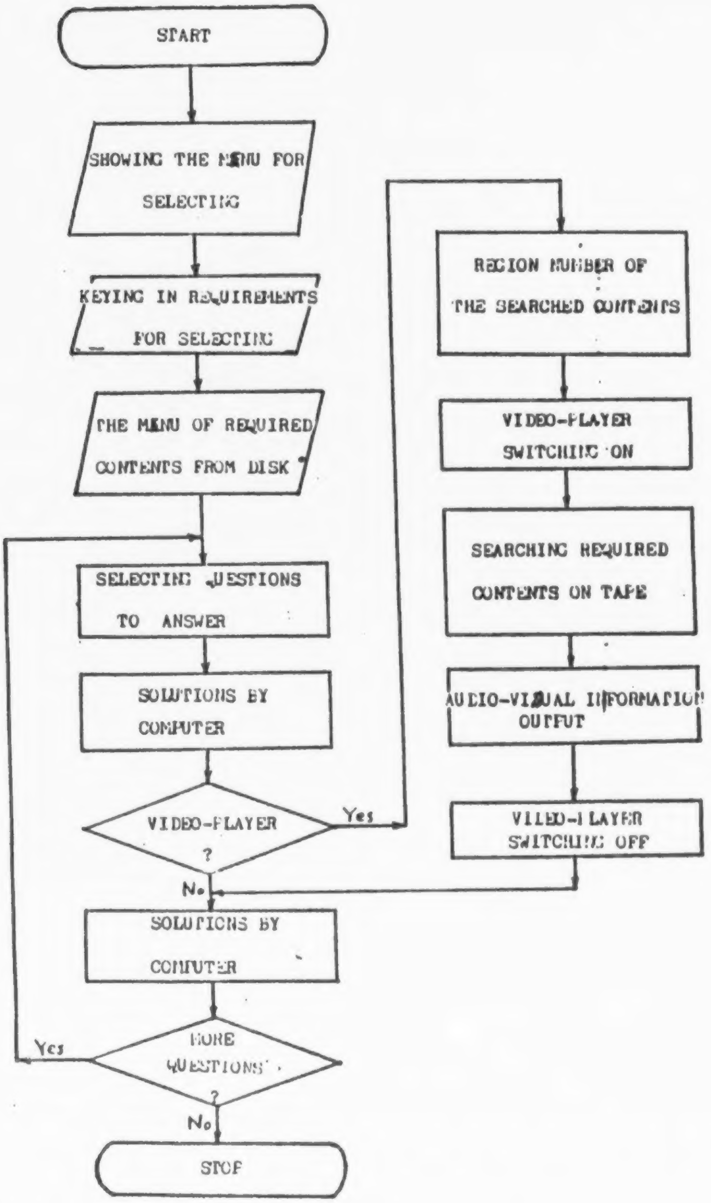

START
SHOWING THE MENU FOR SELECTING
KEYING IN REQUIREMENTS FOR SELECTING
THE MENU OF REQUIRED CONTENTS FROM DISK
SELECTING QUESTIONS TO ANSWER
SOLUTIONS BY COMPUTER
VIDEO-PLAYER ?
Yes
No
REGION NUMBER OF THE SEARCHED CONTENTS
VIDEO-PLAYER SWITCHING ON
SEARCHING REQUIRED CONTENTS ON TAPE
AUDIO-VISUAL INFORMATION OUTPUT
VIDEO-PLAYER SWITCHING OFF
SOLUTIONS BY COMPUTER
MORE QUESTIONS ?
Yes
No
STOP

FIG.IV THE FLOWING CHART OF THE SYSTEM MANAGEMENT SOFTWARE

II. Microcomputer Aided Simulation Teaching in Physics

The essence of the microcomputer aided simulation teaching in physics consists in making use of the excellent graph plotting function of microcomputers to bring physics to life. In this sense it falls under pictorial illustration teaching. However, its function is far beyond those of traditional pictorial illustration teaching mainly in the following respects.

- Diagrams plotted by microcomputers based on accurate calculation, are not only schematic illustrations of physical principles, but real representations of physical processes.
- Diagrams, word description and data presented simultaneousl form a multiinformation measure of illustration.
- Microcomputer aided simulation simplifies physical phenomena, highlights some aspects without other aids of instruments and equipments
- Computer aided simulation reveals more profoundly, clearly, and intuitively physical laws such as composition and resolution o motion, superposition of vibrations and waves, etc. . Such demonstrations may proceed dynamically, and the courses manifest vividly and clearly. The courses of various collisions can be illustrated effectively.
- Computer aided simulation can demonstrate some difficult items than can other traditional ways. For example, the hydrogen atom spectra can be simulated by computer. The spectral series can be displayed individually or collectively. When several neighboring

spectral series displayed simultaneously, all lines of any one of them can be flashed to show its relation to the rest.

- The versatility of computer aided simulation provides possibility to expose a physical process from different aspects and angles. A physical process is dependent on its initial conditions, which can be illustrated with a microcomputer easily to meet various teaching needs. All of these are very helpful to stimulate students to study physics and understand it deeply.
- Microcomputer aided simulation is applicable both for class teaching and for self-study.

The evaluation of the simulation teaching software depends upon the teaching effects. From our experience we present the following rules for the software development.

- Every output information, including graphic data and word description must be consistent with physical laws
- The procedures, steps and logic of the illustration are in accordance with the teaching principles.
- The psycological characteristics of different students (including university students, middle school students, primary school pupils) are concerned for and paid attention to.
- Arbitrary selectivity of its versatile functions
- Dynamical diagrams should be authentic, natural and accurate
- The menu is definite and clear. In particular, the software for self-study should provide explicit hints, and present statements to show how to put in again when incorrect input happens.
- When a program is running, it should not be interrupted by input, except RESET.

- The colors, sound and diagrams not related to the subject should be dealt with carefully, otherwise the teaching effects coul be reduced.

Microcomputer aided simulation illustration may be applied extensively. In class teaching, it is helpful for explaining physic concepts, for illustrating physical phenomena and varieties of processes difficult to observe directly, and for exposing physical laws, etc. . The good controllability of courseware, such as delaye action and selective transfer, is desirable. It is possible to prov softwares for systematic self-study and deepening the understanding the students. Furthermore, students may use specific software to investigate some physical phenomenon under selective conditions and derive related laws through their own observation and analysis. Of course, this kind of software must possess versatile cognitive-functioning. In sum, the graphical function of microcomputers may and should be utilized in physics teaching sufficiently.

III. Microcomputer Aided Examination

Examination, as a guide and impetus to teachers and students,i an organic part of teaching process. With Apple-II Plus microcompute we have successfully developed an application software for physics examination on paper or on computer, and established a library possessing quite a number of questions.

(A) System design targets

- Application software for question input, which is designed for users to build a question library and to supplement question in the library when necessary.

- Application software for question alternation, which is designed for users to revise or delete questions to the library when necessary.
- Application programs for compiling examination questions and printing examination papers.
- Application software for students to answer questions on computer directly and get their marks on the spot.
- Application program for assembling and classifying student's marks and listing them in the order of their results

(B) Theoretical foundation for examination questions selection.

The selection of examination questions is based on the theory of random number generating and random variable sampling. Using a computer, we can produce a series of random numbers r_n by a program according to the recurrence formula

$$r_{n+k+1} = g(r_{n+1}, r_{n+2}, \ldots\ldots, r_{n+k})$$

and then sample them stochastically.

First, we selet m numbers $r_1, r_2, \ldots\ldots r_m$ sequentially from the series r_n. Then we proceed the conversion

$$f(r_i) = L \cdot r_i$$

where L is a conversion coefficient. Thirdly, we can find a value of $f(r_i)$ satisfying the condition

$$0 < f(r_1) \leqslant P$$

where P is the biggest of label numbers of questions in the library $f(r_1)$ obtained in this way is an examination question in the libra satisfying the requirement.

If a paper requires N questions, N sampled values $f(r_1)$, $f(r_2)$ ...... $f(r_n)$ of the random variable can be found accordingly. They are different values. The software in operation can automatically delete any one of them repeating the one going before.

(C) The structure of the system

Our softward, making use of modulized programming and conformi to strict definitions, consists of such modules as question input, question alteration, question selecting, statistics of marks. The flow chart of the system is as follows.

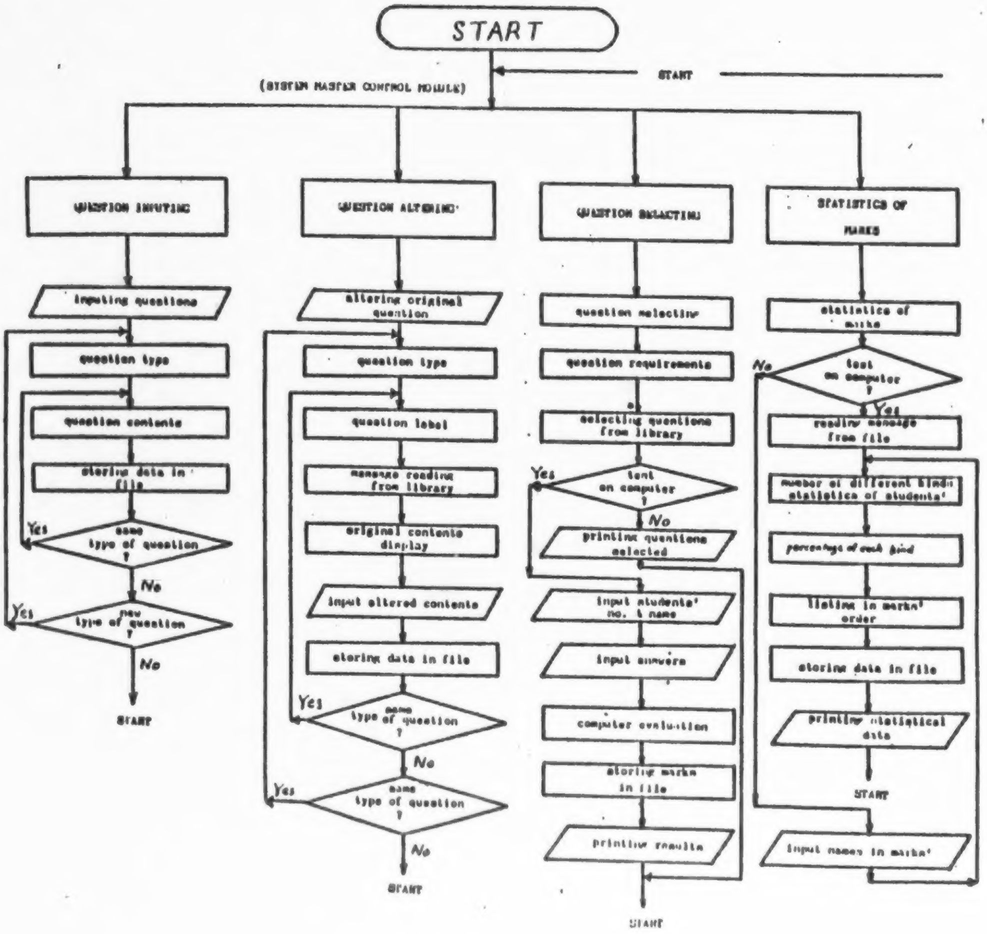

START
START
(SYSTEM MASTER CONTROL MODULE)
QUESTION INPUTING
QUESTION ALTERING
QUESTION SELECTING
STATISTICS OF MARKS
inputing questions
question type
question contents
storing data in file
same type of question ?
Yes
No
new type of question ?
Yes
No
START
altering original question
question type
question label
message reading from library
original contents display
input altered contents
storing data in file
same type of question ?
Yes
No
same type of question ?
Yes
No
START
question selecting
question requirements
selecting questions from library
test on computer ?
Yes
No
printing questions selected
input students' no. & name
input answers
computer evaluation
storing marks in file
printing results
START
statistics of marks
test on computer ?
No
Yes
reading message from file
number of different kinds statistics of students'
percentage of each kind
listing in marks' order
storing data in file
printing statistical data
START
input names in marks'

FIG. V

Application of Microcomputer in Electrical Experiments

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Abstract

The combination of a microcomputer with experiment devices for data collection, data processing and real time control is an important aspect of employing microcomputer in physics experiments. Using microcomputers will promote modernization of the teaching of physics experiments. In this paper, we quote several electrical experiments employing microcomputers which have been arranged for demonstration experiments and for student's selection. As an example, one of these experiments has been described in detail. The software program with its explanation is presented in the appendix. How to introduce microcomputer into electrical experiments and some opinions concerning the application of microcomputers in experiment teaching have been discussed.

The microcomputer has been widely used in physics experiments, and various applications have been rapidly developing in recent years. In previous experiment teaching, a microcomputer with its software was generally used as a calculating tool for processing experimental results, analysing errors and making graphs etc. However, the microcomputer is also a measuring instrument and can be combined with experimental devices for data gathering, data processing and real time control. We think, this is a more important aspect of microcomputer application in experimental technique. A brief account of what we have done in this aspect and some opinions about the application of microcomputers in experimental teaching are presented.

I. Experiments

In physics experiments, various physical quantities need to be measured. With the aid of various sensors, these quantities can be transformed into voltage signals and then transformed into digitals by an A/D converter. The digital signals are then input through an I/O interface into a microcomputer for data analysing and processing. Control signals are afterwards output through a D/A converter to the control circuit for controling the experiment as designed. Using this idea, we have arranged the following experiments:

(1) Measurement of voltage, power and power factor in AC circuits.
(2) Measurement of critical resistance(R) of RLC series circuit in transient process.
(3) Measurement of V-I characteristic of diodes.
(4) Measuring AC hysteresis loop of soft-magnitic material.
(5) Thermocouple calibration and temperature measurement.

As an example, the experiment "Thermocouple calibration and temperature measurement" will be described in more detail here. This experiment is one of the electrical experiments of "General Phycics". In the original experiment, a Ni-Cr, Ni-Al thermocouple was first calibrated by the students themselves at several given reference temperatures (the solidifying points of Zn and Sn metals, boiling point of water and the $0^{\circ}C$ of ice mixed with water). The calibrated thermocouple was then used to measure the solidifying point of tin solder. The thermo-electromotive force (ε) was measured with an automatic potentiometer, which automatically drew the graph of ε vs time (t) on chart paper. Then, the reference temperatures together with their ε values read off from the graph were manually input into the microcomputer for a second order curve fitting. Finally, the unknown temperature was obtained from the calibrated curve of the thermocouple. Here, the microcomputer was only used as a calculating tool to lessen the student's work of calculation. Now, this experiment has been rearranged. A microcomputer is combined with experimental device to form a closed loop system. Data collection, data processing and regulation of the power supply to the stove are program controlled. All the work in this experiment is automatically completed by the microcomputer except for changing the samples. The purpose of doing so is to introduce the microcomputer to students as a new tool for measuring and controlling in experiments. This system is quite simple and easy for students to understand and has the advantage of containing a closed loop control system which is an important experimental arrangement. Students learn that the microcomputer can be used not only for calculation, but also for doing experiments, thus windening their field of vision and knowledge, and making a good foundation for further study.

(1) Experimental set-up.

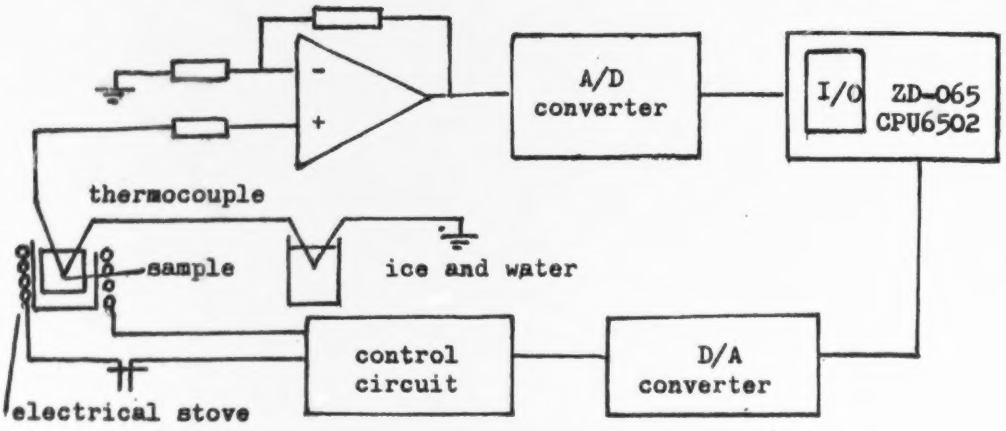

Fig. 1. The schematic diagram of "Thermocouple calibration and temperature measurement".

Fig. 1 shows the schematic diagram of this experiment. The $\mathcal{E}$ value is generally less than 20 mV, and in order to meet the input requirement of the A/D converter (0-5 V); enlarge the range of measurement and improve experimental accuracy, the signal ($\mathcal{E}$) is magnified by a two stage operational amplifier, and then converted from analogue to digital by the A/D converter. The magnified output signal of the D/A converter is used for controlling a relay to turn on or off the power supply of the stove. Eight channel multiswitches are connected to both input and output circuits so that eight experimental devices can be processed in a time-sharing way, thus raising the efficiency of microcomputer, which is necessary for a large class of students.

(2) Experimental results.

After the program is started, the $\mathcal{E}$ values corresponding to the reference temperatures; the calibration curve of the thermocouple got from second order curve fitting; the solidifying temperature of the sample under test and the time dependence of $\mathcal{E}$ corresponding to various samples will be obtained automatically. All these results can be either displayed on a terminal screen, or printed out. The repeatability error of $\mathcal{E}$ corresponding to the solidifying point of the metal is within ± 0.01 mV. The program used in this experiment with its explanation is given in the appendix.

II. Teaching arrangement

In order to gradually introduce the microcomputer into experiment teaching, we have tried the following aspects:

(1) Handling data with a microcomputer.

In those experiments where a lot of data has to be handled (for example, "Thermocouple calibration and temperature measurement"; "Electrostatic field simulation" and "Sensitive ammeter" et al.), students are introduced to microcomputer for processing their experimental data. Doing so helps students to preliminarily know how to use a microcomputer for data processing, on the other hand, it saves a lot of time which can be spent in analyzing and discussing experimental results in more detail.

(2) Demonstration experiments in class.

For example, after students finish measuring a hysteresis loop by the traditional method (using shock ammeter), the teacher demonstrates the measurement of an AC hysteresis loop with a microcomputer in class thus introducing the microcomputer as a new measuring instrument. Here, stress is put on a comparison of the new method with the traditional one.

(3) Experiments for selection by students.

Several experiments employing the microcomputer are arranged for selection by the students (such as, " Measurement of V-I characteristic of diodes " and " Measurement of voltage, power and power factor in AC circuits "). After studying BASIC language, students may select these experiments as they wish. Before class the students preview the basic principles of data gathering and in class, refering to a concrete system, the teacher explains the measurement system and assembly language chart concerned. Then, students do an experiment in accordance with a operation manual. Through this, students come to appreciate the whole process of data gathering with a microcomputer.

III. Some opinions about the application of microcomputers in experiment teaching of "General Physics".

(1) Employment of microcomputers is bound to be brought about.

A microcomputer can measure quantities with a speed and accuracy difficult to achieve by traditional means. Therefore, a microcomputer is suitable for studying transient processes and doing experiments repeatedly under various conditions so as to analyze physical phenomena for regularity. It is obvious that employing microcomputers in physics experiments will raise the experimental level, aid students to understand physical laws deeper, and as a result, improve the quality of teaching. We think, it is necessary for first and second year students to learn to use the microcomputer both as a calculator and as an instrument.

(2) The relationship between traditional experiments and the use of the microcomputer.

Traditional experiments using standard methods and principles enable students to be strictly trained in basic experimental skills and are still the main content for a course in experiments. However, looking at the development of science and technology, we find that the microcomputer is being used more and more in modern instruments for data gathering and real time control. So, in order to keep up with this new development, it is necessary to introduce the microcomputer into experiments. We think, this will arouse the student's interest and promote study, will free students from data recording, data calculating and graph drawing, so that they can spend more time and vigour in understanding and mastering new experimental methods and techniques.

(3) Feasibility.

Our experence shows that, if suitable hardware interfaces and a plentiful supply of subroutines are available for the student's use, after a short period of training in BASIC language, it is feasible to introduce microcomputers into experiments of " General Physics ". We believe that the microcomputer is bound to gradually enter into the physics laboratory and bring about a completely new appearance in experiment teaching.

Appendix: Program used in " Thermocouple calibration and temperature measurement " and its explanation.

The master program is compiled with BASIC language, while assembly language is used for data gathering and temperature controlling.

(1) Extraction of weak signals.

Owing to instability of the power source and the DC amplifier and interference from other source, there will be a lot of noise at various frequencies in the gathered signal. Noise can be significantly eliminated by utilizing one distinguishing feature of the microcomputer which is to sample signals at high speed. That is, each value of ε is obtained from the mean of more than five hundred gathered sibnals, which are sampled at a regular time intervals (some tens of μS) within a period of 0.02 S (see master program line 14 -- 36). The ε values corresponding to reference temperatures and the unknown solidification temperature (for example, ε value of the solidifying point of tin metal) are determined from the mean value of all ε_g sampled during a whole solidifying process (master program line 95 -- 110). From repeated measurements, we found the error of ε was within ± 0.01 mV. It is helpful for the student's work in the future to learn this commomly used method for extracting weak signals.

(2) Graphing.

The microcomputer used (model ZD-065) can only graph with low resolution and display 24 lines on the screen. In order to emphasise the time dependence of ε during the melting and solidifying processes of the metal, for each sample, a voltage value W(mV), a little less than the value of its solidifying point, is chosen as reference. Only those values, which are larger than W and less than W+23, can be picked out and traced on the screen. This means that only ε values near the melting or solidifying point are selected and enlarged. The starting point of the vertical coordinate is at W(mV) and the graduation is 0.1 mV (master program line 60 -- 75).

(3) Temperature control.

When the program is started, a control signal is given out by the microcomputer through the D/A converter to the relay circuit, and the power supply of the stove is automatically turned on (master program line 12). When the temperature of the sample is higher than a certain point and its corresponding ε value reaches a given voltage P(mV), another control signal is given out to turn off the power supply of the stove (master program line 42 -- 56). Then, the ε values during the whole melting and solidifying processes can be measured, and the over heating of the sample, which wastes experimental time in the oeiginal experiment, can be avoided.

BASIC language master program.

```
 1 DIM A(100)
 3 DIM B(5)
 5 FOR Q = 1 TO 5
 7 PRINT "P=?MV","R=?","W=?MV",
   "(R1/R2)=?"
 9 INPUT P,R,W,(R1/R2)
10 Y=0
12 Q=USR(&"OF85",0)
14 Q=USR(&"OF40",0)
16 X=0
18 FOR I=1 TO 568
20 B=PEEK(3072+I)
```

```
22 B=B+5.05/128/546
24 B=B*(R1/R2)
26 X=X+B
28 NEXT I
30 X=X*1000/568
32 X=INT(X*100+0.5)/100
34 A(Y)=X
36 PRINT "A(";Y;")=";X;"MV"
38 IF X P THEN 42
40 QOTO 44
42 Q=USR(&"OFA5",0)
44 FOR J=1 TO R
```

```
 46 NEXT J
 48 PRINT
 50 Y=Y+1
 52 IF Y=100 THEN 56
 54 GOTO 14
 56 Q=USR(&"OFA5",0)
 58 PRINT CHR$(27)+"E"
 60 FOR I=1 TO 100
 62 IF A(I)>W AND A(I)<(W+23) THEN
    66
 64 NEXT I
 66 J=I; E=0
 68 FOR I=1 TO 72 STEP 2
 70 F=J+I
 72 D=INT((A(F)-W)*10+0.5)
 74 E=E+1
 76 PRINT CHR$(27)+"-"+CHR$(24-D+
    32)+CHR$(E+32);"*"
 78 NEXT I
 80 BIG A(I)
 82 M=1
 84 FOR I=2 TO 100
 86 IF BIG>A(I) THEN 92
 88 BIG=A(I)
 90 M=I
 92 NEXT I
 94 PRINT "BIG=";BIG;"MV";"M=";M
 96 S=0;K=0
 98 FOR M=M TO 99
100 T1=A(M): T2=A(M+1):
    T=ABS(T1-T2)
102 IF T 0.02 THEN 106
104 S=S+A(M): K=K+1
106 NEXT M
108 B(Q)=S/K
110 PRINT "B(";Q;")=";B(Q);"K=";K
112 STOP
114 NEXT Q
116 DIM X(4), Y(4)
118 FOR I=0 TO 3
120 READ X(I), Y(I)
122 DATA 0,0,100,1E+4,231.8,5.371E+4
    419.58,1.7604E+5
124 NEXT I
126 FOR I=0 TO 3
128 L1=L1+X(I)
130 L2=L2+Y(I)
132 L3=L3+X(I)*Y(I)
134 L4=L4+X(I)*X(I)
136 L5=L5+Y(I)*Y(I)
138 L6=L6+B(I)
140 L7=L7+X(I)*B(I)
142 L8=L8+Y(I)*B(I)
144 NEXT I
146 N1=(L1/L4)*(L1/L4)-L4/4
148 N2=L1/4*L2/4-L3/4
150 N3=(L2/L4)*(L2/L4)-L5/L4
152 N4=L1/4*L6/4-L7/4
154 N5=L2/4*L6/4-L8/L4
156 A=(N4*N3-N5*N2)/(N1*N3-N2*N2)
158 C=(N1*N5-N2*M4)/(N1*N3-N2*N2)
160 PRINT "E=";A;"T+";C;"T*T"
162 F=B(4)
164 T5=(SQR(A*A+4*C*F)-A)*0.5/C
166 PRINT "T5=";T;"(C)"
168 END
```

Assembly language subroutine(CPU 6502).

For data gathering, the subroutine entry address is $0F40, the gathered data are put into the addresses $0C00 through $0EFF. For turning on and off the power supply of the stove, the subroutine entry addresses are $0F85 and $0FA5 respectively.

```
$0F40     LDA#$00
          STA$A803
          LDA#$FF
          STA$A802
          LDA#$68
          STA$A800
          LDA#$00
          STA$A800
          LDA#$00
          STA$01
          LDA#$0C
          STA$02
          NOP
          NOP
          NOP
          NOP
      C1  NOP
          NOP
          NOP
          NOP
      C2  LDA$A801
          STA($01),Y
          LDA#$FF
          STA$A800
          LDA#$00
          STA$A803
          INY
          BNE C1
```

```
             INC$02
             LDA#$0F
             CMP$02
             BNE C2
$0F82        RST
$0F85        LDA#$FF
             STA$AC02
             STA$AC03
             LDA#$00
             STA$AC01
             LDA#$4F
             STA$AC00
             LDA#$80
             STA$AC01
             LDA#$40
```

```
             STA$AC01
$0FA2        RST
$0FA5        LDA#$FF
             STA$AC02
             STA$AC03
             LDA#$00
             STA$AC01
             LDA#$00
             STA$AC00
             LDA#$80
             STA$AC01
             LDA#$40
             STA$AC01
             RST
```

A GRADUATE PROGRAM IN SCIENTIFIC INSTRUMENTATION

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ABSTRACT

With the support of the Division of Graduate Education in Science, National Science Foundation, an interdisciplinary Master's Degree program in Scientific Instrumentation has been developed in which students participate in the work of a variety of laboratories doing research in biology, chemistry, engineering, physiology and physics. The program accepts students from all sciences. Training with contemporary electronic devices and methods has enabled the students to contribute effectively to laboratory research in areas quite different than their undergraduate training. Experience has shown that students have been highly motivated by instrumentation projects which contribute to real research work, and can progress quickly with a minimum of formal lecture courses.

I. INTRODUCTION

This program represents a major departure from the traditional graduate physics curriculum. The intent is to provide students with a two-year involvement in multidisciplinary research using scientific instrumentation.

The design of experiments and use of transducers, electronics and microcomputers in the collection of data are skills which many physicists have mastered and which are becoming increasingly useful in biology, chemistry, physiology, medicine, environmental sciences and even in the social sciences. A student who can design a system of scientific instrumentation to perform a specific task is able to participate and contribute to research in any of these experimental sciences. This program is flexible enough to allow students to explore a variety of these disciplines by participating in ongoing research in the fields of their choice. The program has evolved over the years from lecture courses to an emphasis on laboratory work.

The first year of the two year program consists of three main parts: A 3-quarter seminar course where the students discuss their laboratory work, a 3-quarter electronics lecture, and a laboratory course where students work on assigned problems and problems for research labs. During the second year, all of the student's time is spent in the laboratory, most of it on the student's final thesis project.

Electronics

The three quarters of electronics lectures are designed to take students with little or no background in electronics to the point where they can design up-to-date electronic instruments. The text which is used is the Art of Electronics, by Horowitz and Hill, a no-nonsense text which covers, quite well analog and digital electronics. We have found it very productive to start electronics with the study of the microprocessor, rather than end with it for two reasons: The first is that no electronics background is required for the student to learn about microprocessors and assembly language programming, and the second is that we now consider the microprocessor as the core of scientific instruments, and one should learn about the core before he learns about the attachments. We spend one quarter blending lecture and lab together so the students can rapidly learn the use of a microprocessor. The students purchase their own microcomputer boards (Motorola 6809) for about $200, and the lab provides terminals and other devices that are needed. By the end of the first quarter, the students will have completed, at their own rate, from 10 to 30 small projects using the microcomputer. The projects include both programming and hardware interfacing. More advanced students will also learn about the 68000 processor and C programming.

In the second quarter the lectures turn to analog electronics, and in the lab the students begin building amplifiers and other analog devices. During two weeks of this quarter we usually split the class into three groups and have them compete to see which group can build the best temperature regulator using their skills in analog electronics and microcomputers. In the third quarter we continue into digital electronics. The lab projects continue to increase in complexity, and in the third quarter the better students will begin work on real projects for various research groups.

Again, we feel that the real learning is in the lab with students working on unstructured projects at their own rate. Each students has his own bench in the lab where he can "live" during the day and usually in the evening. The lab has no fixed hours. It is a place where students can seek help from each other and offer help.

Seminar

Three times a week during the first year the students have a one hour seminar where 1) researchers present problems they would like students to work on; 2) students discuss solutions to problems which are presented; and 3) students present items of general interest such as optical detectors and displacement transducers. The seminar is designed to allow students to present ideas, even if they feel they are crazy, and to criticize and contribute to other students' ideas.

Research Participation

As soon as it is felt that students have a good grasp of solving instrument problems in the lab, they are encouraged to become involved in "real" instrumentation problems with research labs on campus or in local industry. The problems are ones in which the researcher cannot buy what he needs, either because it doesn't exist or he doesn't have the funds. These projects last from 2 months to 6 months and give the student a good idea of real-life instrumentation problems and the opportunity to use his own ideas to solve them. Good students will typically do about 3 of these real projects before he graduates, the last project being called his thesis project. Examples of projects which students have worked on over the years include:

1) A sound spectrum analyzer using the TMS 320 Signal Processing chip.
2) A data recorder for wind generators.
3) A system to measure fluorescence dilution curves in the bloodstream.

4) A fluorometer to measure blood flow in tissue.

5) An infrared scanning detector.

6) An underwater data recorder for monitoring temperature changes in a lake.

We find that students at the Masters degree level have rarely had the opportunity to work on a difficult problem which has many solutions, in which they must find a good (not necessarily the best) solution and then prove it is a good solution by making it work. In most of their schoolwork there was only one solution to problems or, as is done in undergraduate labs, the solution was given and all the student had to do was to apply it. In the research projects we try to provide the student with the problems and the facilities, and let them do the learning on their own with very little supervision. In many cases the problems are in areas the student knows little or nothing about, and must do a lot of individual reading to learn about his subject. This we feel is a good education for later life where the student will have to learn on his own to keep up with progress, especially in instrumentation.

Results

We feel the program has added a degree of freedom to many of the students who have taken it. The ability to understand and design instrumentation is valuable in all scientific areas, and students who have taken the program have gained the flexibility of either returning to their previous field of study or going into new fields with equal ease. For instance, a student with a BS in biology now works at the IBM Research Center designing test instrumentation for new disk drives, and a student with a BS in chemistry now heads the electrical design in our physics department. About 10% of the students have continued on for a Ph.D. degree.

The most interesting thing that we have learned is that there seems to be little if any correlation between the progress a student makes in this program and the area in which his BS was obtained. Good biologists do as well as good engineers. It wasn't the detailed subject matter that the students had learned in their undergraduate studies that made the difference; it was whether they were bright and whether they could learn on their own, given a tough problem.

Students from the program have obtained jobs quite easily, competing usually with electrical engineering graduates. Of course there have been many jobs available in the area of instrumentation, but we think, from what feedback we have had, that the students' experience at solving problems is appreciated by industry.

A DIODE STAR ATLAS - A METHOD OF POINTING AT STARS

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Astronomy has always fascinated students of all ages. Why do the star twinkle? How far away are they? Some are red and some orange, yellow or blue but you never see green stars. Why?

Answers to such questions are based on knowledge of physics where we study density, refraction, temperature and colour. In physics we also teach the student how to measure e.g. small or big distances. Physics is not an easy subject to study but it´s possible to make it more interesting for the students if you start with some astronomy where a lot of physics questions are raised. Astronomy is therefore a very good subject as an introduction to physics. Later cosmic problems can be discussed during a physics course.

If you take your students outdoors on a starry night to look at the stars you are immediately faced with another problem. You would like to point at a certain object but no pointer can reach the distant stars. An ordinary star atlas needs some light and it´s too small to use in front of a group of students. Therefore I have invented "The Diode Star Atlas" on wich I can switch on one star-constellation at a time.

When pointing at a star, e.g. Mizar, on this Diode Star Atlas it´s very easy for the students to find it in the Big Dipper in the sky. Mizar and its faintly visible companion star Alcor form a double star system. People with good eyes can just distinguish them as two stars without help of binoculars. The angular distance between them is only 11 arc minutes.

The Diode Star Atlas has a size of 60 cm x 60 cm. On this area 20 different objects can be shown by help of light emitting diodes.

A RADIOACTIVE SOURCE PRODUCED IN THE CLASSROOM

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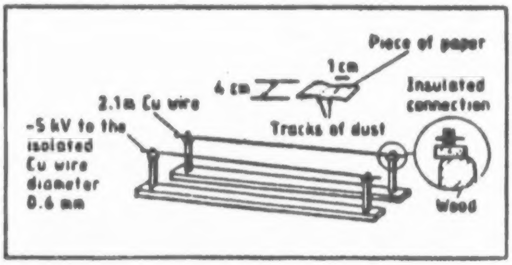
Radioactivity in our environment is an increasingly important subj Ionizing radiation (α, β, γ) from radioactive atoms far above the nat al background can cause damage to cells in our body.

Instead of buying and storing expensive and dangerous sources at school we can easily produce a strong radioactive source from radon daughters usually available in each classroom or in the cellar of the school.

Radon is a radioactive rare gas. It is produced from radium which a half-life of 1600 years. Radium itself is a product of uranium. Bot uranium and radium are present in many materials: e.g. granite contai 2-40 g tonne^{-1} of uranium and alum slate (shale) contains 10-350 g tonne^{-1} uranium.

Radium is always fixed to the surrounding material but it is continuo ly decaying into radon. Radon being a neutral gas moves easily throug the ground or wall material. The radon atoms have a half-life of 3,8 during which time the gas may leak into the house even if we try to p vent it. If a building is poorly ventilated the indoor air will, in a few hours, contain a high level of radon. The radon daughters Ra A, Ra B and Ra C are electrically charged atoms and do therefore stick t small dust particles. Such charged particles may be collected with the help of a wire of large negative potential, -5 kV (see figure). After a short collecting time, e.g. 10 minutes, the wire is wiped off with a soft paper. Dust particles on which radon daughters are fixed will th be collected on the paper - a radioactive source is produced.



Electrostatic collecting wires.

See further information in an article by L. Samuelsson: "Radon in dwellings a high voltage method for a fast measurment of rad daughter levels". To be published in European Journal of Physics autumn 1986.

PRACTICE IN TEACHING OF PHYSICS EXPERIMENT IN ENGINEERING COURSE

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Proceeding from the higher engineering education in its entirety, and in the light of the basic requirements for cultivating higher technical personnel in engineering course, we think, in order to cultivate the experimental ability of college students majoring in engineering, it is necessary to set up a complete system, which, from the standpoint of scientific experimental physics, must contain programming, instrument disposition, data collecting and processing, error analysis and result evaluation. As an elementary course-physics experiments independently (about 20 experiments in general), neglecting in teaching systematic theory and syntheic analysis, and overemphasising the measurement of some physical quantity at the expense of mastering the methods of experiments and observing the phenomena of experiments. We deem it can hardly meet the above requirements. Considering such situation, combinated with the existing conditions of our country, we have made several approaches to the reforms in the structure, contents and teaching methods of physics experiment. Some reforms have already been carried out and some just begun. Generally speking, they are practicable.

(A) Historical Retrospect

With respect to the contents of the current experiment teaching materials at home and abroad, and earlier those, there are two structures: (1) comparatively compact and marrow combination with theoretic teaching materials, that is, mechanics, heat, direct current, light and modern physics in sequence, (2) broad classification according to the systems, e.g., electromagnetics, microelectronies, optical spectroscopy, radiation measurement, etc. The former is more widely adopted in our country. The latter is particularly prevalent abroad. But both have a common characteristic: apart from the explanation of errors in measurement and data processing (often at the beginning), the contents are mostly single and separate physics experiments (but better organized in Berkeley's course), and too much emphasis is placed on the measurement of physical quantity, especially in the current teaching materials of our country.

Let us look at the teaching procedure. The current teaching links in our country consist of students' studying beforehand and preparing the experiment according to the principles and methods given in the teaching material, performing the experiment in the lab and finally working out a report. The outstanding characteristic of this procedure is to strictly limit the students' thinking within the scope of the teaching material as well as the conditions given in the lab. Hence it is hardly possible to cultivate every student's independent working power. Lastly, the schedule of every college is prearranged, students study in accordance with a fixed table which greatly limits their initiative and selfconsciousness.

(B) Problems Put Forward

In view of the above-mentioned situation, the current teaching system and method have the following drawbacks:

(1) The teaching contents only give the final conclusion, without

explaining clearly what to do in the experiment, hope to do, how the design comes out, how to choose the program and how to make use of the conditions. Take the analogy of static electric field as an example. The title of the experiment is the static electric field, but students are asked to survey the voltage distribution of the alternating current field. Why can the alternating field be analogous to the static? What relation exists between them? What is the analogy method? What conditions are there? Very few of such questions are given in the teaching material. In the lab students are busy for measuring the quantities, having no time for thinking of these questions. So when the experiment is over, better students might remember a bit, but students at large quickly forget. Regarding how to trace the power lines out of the measured equipotential lines, they can only draw a few lines arbitrarily by sheer subjective imagination. This will cause some conceptive mistakes, such as, break of power line, non-vertical intersection of power line and equipotential line, or contradiction between power line spacing and field intensity distribution.

Such practice is harmful to the cultivation of ability for students to master the process of thinking of experimental physics, step by step.

(2) All instruments to be used are well adjusted and placed before the students. But they have no idea of why such instruments are chosen. Take the experiment of Young's Modulus of metals as an example. It summarizes nearly all conventional methods of length measurement. In this experiment the metric rule, vernier caliper and micrometre are used. But before making the experiment students can in no way understand the result errors are largely due to measuring the diametre with the micrometre. Why so? Even after the experiment few students can give a correct answer. This shows they can make use of instruments at most, but anyway they cannot learn how to choose instruments, let alone doing harder task, such as, linking instrument disposition with errors as well as data processing.

(3) It is important in cultivating the experimental ability of a student to find out the corresponding physical model in the task given, and then, based upon relerant theories and experimental data to attain the expected goal. For example, in the experiment of studying the diode volt-ampere characteristics, the general requirement is to draw a volt-ampere characteristic curve or rerify the 2/3 square-root method. In fact, it is deduced from the uniform field of infinite parallel plate. If we change the process of the experiment by drawing the I=f(u) curve first, choosing points in the curve and processing the data, we can get the coefficient and set up the functional equation. Further, analogize with the field of infinite parallel plate electrical condenser, the problem can be satisfactorily solved.

(4) Experimental teaching should enrich the contents of classroom theoretic teaching, forms should be very vivid. The current stereotyped teaching can hardly help bright students make great progress and backward students solve difficulties. Thus we are not capable of teaching students in accordance with their talents and cultivating excellent engineering personnel.

(C) Our Approaches to Teaching Reform

(1) Reforming the current teaching material is the chief link. Instead of the original structure of single experiment, reorganized teaching

material consists of physical thoughts, basic measurements, methods of experiment, program designing, comparison and choice of instruments, data processing and error analysis. Through this course of study, students may have a fundamental and integrate concept of how to perform an experiment. Moreover, they may go through a training of a considerable number of basic experimental methods. We cast off the past "spoon-feeding" teaching material with aims, instruments, principles, steps and even data tables given. We compiled the material systematically, putting together the contents of common nature, such as, basic quantity measurement. For each experiment, only physical models are given. Students have to arrange steps and data tables for themselves. Recommendations for the use of instruments are given as little as possible, so that students may learn how to use instruments in the shortest period with the help of directions.

Of course, it is too difficult for freshmen who have just left middle school. So we have a few experiments written very clearly to help them facing some steps at the beginning.

All that students can do by themselves should be done by themselves repeatedly so that they may lay a solid foundation. In the past, for the sake of emphasis, some basic trainings were inappropriately cut down. For example, amounts that students could measure by themselves were given. Many instruments were used only once or twice. It was far from adequate. In order to give students strict training, we may purposely cut a wire in the circuit to cause trouble, the removal of which rested with the students.

Another example, formerly the parameters (geometric size and quality) of all test-pieces (disks or rings) were given. Now we provide balances and calipers for students to measure by themselves. In the circuit experiment, avometers are provided for students to find out the pressure gear and remove the trouble.

(2) We properly assigned a few "reversing" or "designing" experiments with the object that students might have an opportunity of understanding the development of science. For example, the three-line suspension pendalum was not verified, but measured through the relation between cycle T and rotation inertia J. We let student set up $T=KJ$ and find out K and (equal to $\frac{1}{2}$) so that they could make a comparison between experimental equation and theoretic equation to deepen their concepts. Before making independent "designing" experiment, let students design a part, such as, calculating and selecting of potential divider in the circuit.

(3) We develop the "second classroom" to lead students into a vast world. The lab is open to students as frequently as possible. They may enter it freely, enabling them to make deeper study and develop their intelligence. Now a lab has purposely been opened to students newly enrolled. We are setting up another lab for students who have finished experiments but wish to do more as they like. But for the moment this lab cannot accommodate too many students because of limitation of conditions.

(4) With the popularization of microcomputer, while laying emphasis on basic error calculation, we introduce linear combination and statistical processing of experimental data, - the rectangle chart into physics experiment. This can deepen students' concepts of data processing and errors, and can play an active role in improving students' ability of handling microcomputer as well.

At present, in the three experiments —— "resistance temperature coefficient", "study of the three-line suspension pendulum cycle" and "measurement of liquid viscousity coefficient" —— we use linear combination by the least square method, and in the "measurement of basic charge" data processing by the rectangle chart. Effects are rather satisfactory.

(D) Practicability and Effects

For nearly two years we have carried out a part of what has just been said, and others will be done in this year and the next. Considering what we have heard from our students and the results of exams and tests, we think a considerable part of our reform is practicable, though there are a lot of difficulties. The old teaching material needs revising, while the new teaching material will not be ready until next year. But through trial-teachings in two big classes of out university in 1985, the new method did win popularity. Formerly we worried about the difficulty students might meet in processing data by the least square method, but now we think the new teaching method is acceptable to students and many of them have gained a deeper understanding. Formerly we worried about the present "trouble" in the circuit would be too difficult for students to tackle and would probably cause damage to instruments, but now we think there will be no problem. This experiment has gone through very quickly. We are going to enrich its contents. As students have made some progress in the mastery of experimental method, understanding of physics concepts and recognition of datum diagram method; we will give "reversing" experiments in the "three-line suspension pendulum" and the "diode voltampere characteristics".

In short, a separate course of physics experiment has brought along a lot of problems. The development of science and technology has set new demands upon high engineering education. All these require us to change the old state quickly and seek a system to suit the new. What we have done is very little and immature. Many problems are waiting to be explored and approached. We beg all specialists and scholars here to give us directions.

IMPLICATIONS OF RESEARCH AND NEW TECHNOLOGIES FOR TEACHER EDUCATION AND PROFESSIONAL DEVELOPMENT

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ABSTRACT

Specific examples are given of some of the insights being gained through recent research on students' difficulties in concept formation and in development of understanding of laws and principles. The role that this knowledge should play in teacher education is discussed, and a connection to computer based instruction is briefly sketched.

1. Introduction

During the past fifteen years, research in physics education has been deepening many of our insights into practical aspects of teaching and learning. The nature of student difficulties with various aspects of abstract logical reasoning, with concept formation, and with understanding of physical laws is being identified and clarified. Indications are being developed concerning better ways of conveying genuine understanding as opposed to memorization of procedures. Information is also being gained on the rate at which subject matter can be fruitfully covered and on the extent of cycling back and repetition needed by different students.

The bibliography at the end of this paper cites references representative of such investigations and inferences. The bibliography is neither complete nor exhaustive; it is intended only to give newcomers to the literature an introduction to the field, an overview of the range of work being done, and the essence of some of the conclusions being reached.

Among the principal insights emerging from these investigations are the following: (1) Many students have serious difficulty with basic modes of abstract logical reasoning (controlling variables; arithmetical reasoning involving ratios, division, and scaling; discriminating between observation and inference; doing hypothetico-deductive reasoning) and need repeated practice in altered context to develop and enhance this capacity. (2) Successful solution of typical end-of-chapter problems frequently conceals serious gaps and deficiencies in the formation and mastery of the most basic concepts such as velocity, acceleration, force, mass, energy, electrical charge. (3) Solution of conventional problems also conceals widespread failure to grasp the most basic phenomenology, e.g. that of the simplest dc electrical circuits or of image formation by mirrors and thin lenses. (4) Very robust and persistent intuitive preconceptions, drawn from everyday experience with motion, seriously impede understanding the law of inertia and formation of the Newtonian concept of force, and are not altered in many students through conventional presentation and explanation. (5) Although skillful and lucid presentation and explanation are highly desirable components of instruction, they nevertheless fail to achieve their ends unless the mind of the learner is engaged *actively* (not passively) through concrete experience and through several episodes of spiralling back in altered and enriched context. (6) Many students do not break through to mastery of such abstract concepts and lines of reasoning without being helped to articulate conclusions and explanations in their own words through the medium of Socratic dialog.

It is clearly important for teachers to have fully mastered the concepts and lines of reasoning themselves and to have acquired intimate knowledge and awareness of the gaps and difficulties endemic in the minds of their students. It is therefore essential that insights such as those developed in the appended bibliography become an integral part of teacher education.

2. Ratio Reasoning

Student difficulties with all kinds of ratio reasoning (simple proportional reasoning; word problems involving interpretation and use of division; scaling and functional reasoning using ratios) have been documented and described by McKinnon and Renner (1971), Karplus, et al (1979), Arons (1976, 1983b), Chiappetta (1976), and many others. Stevenson, et al (1986) document superior level of mathematical achievement of Chinese and Japanese children relative to American children, but serious difficulties with such reasoning arise in a significant fraction of virtually every student population. American college students in engineering physics courses, for example, exhibit very severe deficiency in their ability to deal with ratio reasoning in geometrical scaling or in functional variations involving direct or inverse powers of an independent variable [Arons (1983b)].

The great majority of students can be helped to overcome these deficiencies through *repeated* practice. Such practice must include the opportunity for each student to explain the line of reasoning in his/her own words. The practice must take place within the subject matter of the physics course itself, must be spread out over time, and must be invoked in altered, increasingly rich. context. Preliminary, rapid remedial exercises in artificial context are ineffective. Approximately five episodes are necessary in each kind of reasoning before success rate rises to about 85% with U.S. students at college level [Arons(1983b)].

Student difficulties with all the different forms of ratio reasoning can and should be remediated prior to college - university level. This can be accomplished by making sure that teachers have developed the necessary capacities themselves: they should be able to do the reasoning and explain it clearly in their own words; they should be keenly aware of the existence of the difficulty among students and should be capable of identifying those students who have surmounted the difficulty and those who have not; they should be able to devise questions and problems that induce fruitful practice of ratio reasoning in any relevant subject matter.

3. Kinematics, Gravity, and Free Fall

Many useful insights are being developed concerning widespread, and hitherto poorly perceived, student difficulties in forming the concepts of position, instant, velocity, acceleration and in misconceptions concerning everyday gravitational phenomena: Arons (1981b), Peters (1982), Trowbridge and McDermott (1980, 1981), Gunstone and White (1981).

Numerous difficulties are superposed in this area: failure to assimilate operational definitions and attendant failure to separate the underlying idea from the technical name; confusion between "protoconcepts" of position and velocity and of velocity and acceleration; difficulty with translation of verbal descriptions into graphical representations and interpretation of graphs in words; failure to possess meaningful operational definitions of "vertical" and "horizontal"; belief that gravitational effects vanish in the absence of air; belief that an object nearer the ground is "heavier" than a balancing object higher above the ground (for human scale distances in which the differences in gravitational force would be unobservable); describing the symbol g as denoting "gravity" without invoking the term "acceleration"; and so forth.

Teachers should be made explicitly conscious of these difficulties and of the fact that many of the questions, demonstrations, and exercises through which these difficulties are revealed are themselves useful exercises in helping the student confront contradictions and resolve misconceptions and confusion.

4. Understanding the Law of Inertia

Because of the obvious conceptual importance of the subject matter, the preconceptions students bring with them when starting the study of dynamics, and the difficulties they encounter with the Law of Inertia and the concept of force, have attracted extensive investigation and generated a substantial literature. A sampling of useful papers, giving far more extensive detail than can be incorporated into this section, is cited in the bibliography [Champagne, Klopfer, and Anderson (1980); Clement (1982); di Sessa (1982); Gunstone, Champagne, and Klopfer (1981); Halloun and Hestenes (1985); McCloskey, Camarazza, and Green (1980); McCloskey (1983); McDermott (1984); Viennot (1979); White (1983), (1984)].

Learners' difficulties in encompassing the Law of Inertia and the concept of force stem in large measure from the wealth of common sense preconceptions and experiential "rules" that most of us assimilate to our view of the behavior of massive bodies before we are introduced to Newtonian physics. Some of these views are Aristotelian (e.g. the necessity of continued application of a push to keep a body moving (it is very difficult to abandon thinking of rest as a condition fundamentally different from that of motion, or to accept the view that, rather than asking what keeps a body moving, we should ask what causes it to stop), but many of these commonsense views are more closely related to the medieval notions of impetus associated with names such as Buridan and Oresme.

All investigations show these "naive" conceptions to be very deeply entrenched and very tenaciously held, and it is important for teachers to understand that student difficulties are not reflections of "stupidity" or recalcitrance. The difficulties are rooted in seemingly logical consequences of perceived order and experience and are vigorously reinforced by insistent use (or actually misuse) of words drawn from everyday speech (inertia, mass, force, momentum, energy, power, resistance) before these words have been given precise operational meaning in physics. Persistent misuse of the terms in thinking to oneself and in communicating with others is a major obstacle to breaking away from the naive preconceptions. (This is another reason for helping the students stand back and become very self conscious about the process of operational definition — term by term.) Some teachers tend to minimize such problems by labelling them as "merely" a matter of language or semantics, apparently not realizing how formidable and significant the linguistic obstacles tend to be.

Investigations of understanding of the Law of Inertia further show that it is far from sufficient to inculcate the law verbally and supplement it with a few demonstrations of the behavior of frictionless pucks on a table or gliders on an air track. Many students will memorize and repeat the First Law quite correctly in words, but, when confronted with the necessity of making predictions and describing what happens in actual physical situations, concretely accessible to them, they revert repeatedly to the naive preconceptions and predictions, giving the disappointed teacher the sinking sensation of not having succeeded in teaching anything at all.

If one wishes to lead the majority, rather than a small minority, of students to understanding the Law of Inertia, one must accept the necessity of providing a wide array of experiences, both hands-on and hypothetical, in which the student makes his own errors, encounters the resulting contradictions, and, forced by these errors and contradictions, revises his preconceptions. Such experience cannot be provided and mastery developed, however, in one short remedial session. The ideas and initial experiences should be introduced while development of the subject matter is continued without waiting for full mastery on first encounter. One then helps cultivate mastery and understanding through repeated spiralling back to qualitative application of the Law of Inertia in increasingly rich and sophisticated physical situations as the study of the science continues.

The most effective, albeit fairly expensive, physical situation I have been able to use to such purpose is one in which a full size 20 kg block of dry ice, with its base smoothed to some degree, is placed on a large glass plate levelled up on a laboratory table. Students are then invited to perform literally "hands-on" experiments (using gloves, of course). A large array of very basic, vitally important, ideas can be developed Socratically in this context*:

(1) How does the block behave once it is moving? What is the difference between this situation and the one in which ordinary objects slide on ordinary surfaces? (The way in which the block moves in ghostly splendor along the plate, especially at low velocity, without appreciable slowing down, makes a deep impression on most individuals who have never seen such effects.)

(2) What action on our part is necessary to make the object move faster and faster, i.e. accelerate continuously? (To many students it comes as a great surprise that they have to move faster and faster themselves to keep up with the block and to keep on exerting the accelerating force. Even though they previously saw the block move at uniform velocity in the absence of an external force, many of them have not translated this into the sensations that go with the exertion of a constant force on an accelerating object.)

(3) What is the difference in behavior of the block when acted on by a steady push that keeps up with the block and when it is given a quick shove? (Many students have not had the opportunity to discriminate between a steady force and an impulse. As a matter of fact, to many students, the word "force" in the context of setting an object in motion means a quick shove rather than a steady action, and it is important to help them perceive the difference.)

(4) How large a force is necessary to impart any acceleration at all to the block, i.e. is there a threshold effect? (Everyday experience indicates that bodies are not set into motion until a certain minimum force is

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* Even though some situation other than the block of dry ice is invoked, the sequence of questions which follows is one through which most students should be led. The difficulties being intercepted are very widely prevalent among students in virtually all introductory physics courses.

exerted; this is one of the eminently reasonable naive rules that students bring with them initially.) The *PSSC* film called "A Million to One", in which a flea is hitched up and accelerates a massive dry ice puck, is well worth showing if it is available.

(5) Suppose the block of dry ice is already moving: what must be done to make it slow down very slowly without changing the direction of its motion? Many students are inclined to apply an impulse rather than a gentle, continuous force. They must be guided into doing the latter, and they are usually astonished to find that they must allow their hand to retreat with the moving block. This experience helps reinforce the discrimination between impulse and steady force.

(6) Suppose the block is moving to begin with, and we exert a steady force, either speeding the block up or slowing it down. How does the block behave? Now suppose we make our steady force smaller and smaller. How does the block behave? How will it behave when the force we are exerting reaches zero? (Note that what is deliberately constructed here is a *reversal* of the usual direction of presentation of the ideas: instead of using the zero force situation as the starting point, we are now starting with the non-zero net force and going toward the zero force condition. Many beginning students, at all levels, have very great trouble with the zero force case, despite all the preceding discussion and demonstration. Reversing the line of reasoning and experience, and seeing the situation both ways, helps in the acquisition of the desired insight.)

(7) Suppose we exert two steady forces on the block in opposite directions, one with each hand. How does the block behave when the one force is larger than the other? when the forces are of equal magnitude?

(8) Suppose the block is moving: what actions change the *direction* of its motion? (Here, once discrimination between the two has been developed, it is possible to explore the effects of both continuous actions and impulses.) What do you have to do to make the block move at right angles to its initial path? in some other specified direction? in an (approximate) circle? (The principal non-Newtonian expectation found among learners is that an initially moving object will move in the direction of the last impulsive push. It is important that they encounter the contra-intuitive phenomenon personally.)

(9) What happens if you start the block spinning about a vertical axis? Without using any as yet undefined technical terminology, what are some implications of the observed behavior?

Some words of caution and advice about implementation of this experience: (a) Its essentially personal, hands-on nature tends to reinforce an idea, deeply embedded in many students, that accelerating effects (forces) are necessarily exerted only by animate beings. One should emphasize that contact interactions between inanimate objects (e.g. collisions, release of compressed springs, etc.) also impart acceleration. Non-contact interactions can be introduced or referred to at the teacher's discretion. (b) Although a very small number of students may successfully explore the physical situation without Socratic guidance and emerge, on their own, with most of the insights listed above, the great majority do not carry out a genuine investigation or draw significant inferences under such circumstances. It is essential that the teacher provide guidance, but this is best done by asking questions and eliciting suggestions from the students rather than by giving a set of instructions to be followed. (c) The whole operation is at its best when, under minimum guidance from the teacher, the students suggest, try, argue, and interpret in their own words, carefully avoiding any, so far undefined, technical vocabulary.

There are, of course, other devices for providing some of the experiences outlined above. A massive dry ice puck does very well on the glass plate, although it is not as dramatic as the 20 kg block. A good bit can be done with pucks on an air table, although their rather small mass makes it difficult to perform some of the more delicate experiments, with small forces, using one's own hands. With both kinds of pucks, it is probably better to use some other device for application of a force—the stream of air from the hose of a vacuum cleaner operated in reverse, for example.

Another mode allowing for the development of individual experience is, of course, computer simulation, and many groups are developing instructional materials to this end [cf. di Sessa (1982); White (1984)]. Where the tactile, kinesthetic experience with real objects is impracticable, computer simulation is undoubtedly the next best mode. Computer simulation is also useful for providing more extended practice in thinking about a wide variety of examples. It is capable of supplying continual feedback regarding error and correctness and reinforcing the hands-on observations after the latter have been carried out. The weakest mode is that of lecture demonstration in which student participation is passive — limited to hearing assertions and to seeing effects produced by someone else.

Pencil-and-paper questions and exercises are also a useful component of instruction. They can be designed to help the student confront contradictions in his/her own thinking and to converge on genuine grasp and understanding. Such questions play an especially important role in homework and on tests and examinations.

5. Phenomena That Elude Direct Sense Perception

One of the most basic examples of student difficulty with phenomena that elude direct sense perception is the tenacious resistance of many students to accept the notion that, when a book rests on a table, the table exerts an upward force on the book. An initial primitive stage is one in which the student believes that forces can only be exerted by animate objects, but, even when this preconception is overcome by appeal to the action of springs and results of collision between inanimate objects, many students still resist the idea that seemingly rigid objects (such as the table) are capable of exerting a force on another object [Minstrell (1982), Clement (1986), Steinberg (1986)].

The investigators show that this resistance is not overcome through assertion and explanation by the teacher, however lucid the presentation and argument may be. Conviction and acceptance develop only after slow and patient discussion of various thought experiments and direct observations. Among these are: interpretation of what one feels personally as increasing load is placed on one's hand; visualizing what happens when one puts objects on beds, soft chairs, and very soft springs; "bridging" between the very soft cases and the hard table by placing the book on a foam pad and on increasingly stiffer pads; visualizing what happens to the table as the load placed upon it increases to the point at which the table itself breaks; making an optical lever by reflecting a beam of light from the table surface to a wall and having the students observe the deflection of the light beam as load is placed on the table; leading students to the ultimate perception that some finite deformation of the table must occur for any finite load however small, i.e. leading them to accept the proposition that the table must deform when a sheet of paper is placed upon it, even though the deformation completely transcends our direct sense perception.

A serious deficiency in much present day instruction in physics resides in the fact that students are not generally led to visualize the details of various processes they cannot see directly. As a result, they frequently fail to understand the most basic phenomena, and they concentrate on problem solving procedures without developing physical insight into the phenomena dealt with in the problems.

In addition to the deformation of the seemingly rigid table under loads however small. there are many other important situations in which similar visualization should be cultivated. The capacity for such visualization develops only rather slowly and only after opportunity for practice in a wide variety of contexts, gradually increasing in richness. Following is a series of examples of such situations; however disparate these situations may initially seem, they are all unified by the theme of visualizing physical effects that transcend direct sense perception.

(1) Visualizing deformations taking place in collisions: As in the case of the "rigid" table discussed above, many students fail to recognize the deformation and springing back that occur when seemingly "hard" objects (such as billiard balls, ball bearings, carts, pucks) collide with each other. They are helped to such insight by the "bridging" afforded by observation of "soft" collisions such as those between carts or gliders carrying soft springs which can be seen to bend and spring back over the interval of collision. Not only does such exposure lead students to recognize the presence of deformations that cannot be seen by the naked eye but it also helps students recognize the finite *time* intervals, however short, involved in the interactions.

(2) Visualizing tension in an accelerated rope or chain: Many textbooks bring forth the word "tension" and start using it as though everyone must know what it means without operational definition. The student is confronted with the familiar problem in which one string is stretched by opposite forces of 50 N at each end while a second string, with one end attached to a wall, is pulled with a force of 50 N . The student wonders how it is possible for the tension in the string to be the same in each case and is unable to see why it is not 100 N in the first string.

There are two difficulties superposed here. One is that, when this situation is first encountered, many students have not fully assimilated the Third Law and, not drawing an adequate force diagram of the string, fail to see that the two situations are identical as far as the forces on the strings are concerned. The other difficulty, however, is that "tension" has not been defined.

One simple approach is to lead the student to imagine "cutting" a stretched string at some point along its length and drawing the forces acting on the two segments. (Not only is this a good exercise in using the Third Law, but it also introduces students to the examination of forces in the *interior* of objects. Up to this point all forces and force diagrams have usually been confined to external effects, and the realization has not been formed that one can, in imagination, "cut through" an object and show the forces at the selected cut.) Having drawn the equal and opposite forces acting on the two segments at the cut, one can give the name "tension at the cut or section" to the magnitude of the force acting on either segment. Tension and compression in rods or columns can then be defined in a similar way. Having defined tension in this way, it is now a relatively simple matter, inviting valuable phenomenological thinking and visualization, to examine the tension in a massive rope (or chain or rod) as the object is accelerated by a force at one end. It is not necessary to solve quantitative problems! As one examines the tension "chunk-by-chunk" through the length of the object, it becomes apparent, through application of the Second Law, that the tension must decrease continuously from a value equal to that of the applied force at one end to zero at the other. One can then leave the further problem of how the tension varies when a rope is accelerated with two opposing forces, unequal in magnitude, at each end.

(3) Two widely used demonstrations of "inertia": Two excellent demonstrations are very widely used to demonstrate what is frequently (much too casually) described, as "inertia":

(a) The table cloth is quickly yanked out from under a set of dishes on a table, leaving the dishes on the table.

(b) A massive block is suspended by a string from a rigid support, and an identical string hangs from the bottom of the block. When the lower string is pulled slowly downward, the upper string breaks; when the lower string is quickly jerked downward, the lower string breaks.

There is much more involved here than just "inertia". Both of these situations are rich in physical phenomena, and students should be led to think about them in some detail in order to understand what is involved. Probably the best way to induce this thinking is to perform the demonstrations and ask enough leading questions (assigned as homework) to make it possible for the majority of students to fill in the gaps without getting bogged down.

In demonstration (a), if the dishes were glued to the table cloth, they would be yanked off the table. The demonstration depends on the fact that the coefficient of friction is sufficiently low to allow the interface to "break" (i.e. sliding begins) at a value of maximum frictional force sufficiently small to impart sufficiently small acceleration to the dishes. Even with a relatively small frictional force, however, the dishes would still be yanked off the table if the table cloth were very long, extending down the table well beyond the dishes. In other words, there is a time element involved, and the demonstration works because the time during which acceleration is imparted is short enough to make the displacement negligible.

The inertia of the dishes is indeed an important factor, but so are the other factors. Viewers of this demonstration are rarely given the opportunity to think it through and understand it fully. Part of the understanding depends on awareness of what *might* happen, of what is *not* the case — in addition to an awareness of what *is* the case and what *does* happen.

In demonstration (b), the crucial physical effect is the *stretching* of the strings to their breaking point. The stretching eludes direct sense perception and therefore has to be discerned in the imagination. Few students perform this act of imagination spontaneously, but it is not difficult to guide them into it. The key is again the element of time (as in demonstration (a), but in a somewhat different fashion): when the lower string is jerked, the low acceleration of the block allows the lower string to be stretched to breaking point before displacement of the block produces comparable stretching of the upper string; when the lower string is pulled slowly, both strings stretch without appreciable time delay, and the upper string is stretched to breaking point first because of the higher loading. (At a still higher level of sophistication, students could be encouraged to visualize the elastic waves that must propagate up and down through the components of the system preceding the displacements leading to breaking.

Without visualization of the stretching of the strings, students acquire no understanding of the demonstration; they simply memorize, and repeat, that it had something to do with "inertia".

(4) The origin of stresses associated with temperature changes: Two widely used demonstrations exhibit the enormous stresses that arise when expansion or contraction due to temperature change are restricted:

(a) A metal rod is heated to over its entire length to a high temperature. The ends of the rod are then pinned to a massive supporting frame. As the rod cools, one of the restraining pins breaks or the rod itself breaks.

(b) Water filling a strong, well stoppered container is cooled till it freezes. The container breaks.

Without explicit guidance, few students visualize what is happening; they fail to think through the origin of the large stresses that develop in these demonstrations. What they fail to perceive is that, in the case of the heated rod, the restraining pins are, in effect, being asked to provide the pull that would have stretched the rod by the amount it had expanded on heating. Similarly, they fail to visualize that, in the case of the freezing water, the container is being required to compress its contents by the amount of the volume change that would have taken place in freezing at atmospheric pressure. These interpretations are completely glossed over and are lost to most students unless the descriptions and visualizations are brought out explicitly.

(5) Effects delayed by short time intervals: Suppose one lays a long metal or wooden rod on a table, prepares to push one end, and asks, "I shall push on this end, and the rod will be displaced. When the rod begins to move, does the far end move at exactly the same instant as the end on which I push, or does a time interval elapse between the effects at either end?" In this situation the great majority of students reveal total unawareness of the tiny elapsed time interval. Even students who have begun to study wave phenomena and who have seen longitudinal waves on a "slinky" (long, soft spring) are unwilling to accept the finite time interval. (Note the similarity to their reluctance to accept the finite deformation of the table under the book.) The students are in need of help and guidance in visualizing the rapidly transient events that can neither be felt nor seen.

It must be emphasized that the phenomenon involved here is far from being special or trivial; it has, indeed, a very deep connection to underlying concepts, laws, and physical theory. During the interval that elapses between the push on the near end of the rod and propagation of the compression wave to the far end, the force exerted on any object at the far end of the rod is *not* equal and opposite to the force exerted by the rod on our finger. In other words, Newton's Third law breaks down over the intervals of time and distance involved, and the "action-at-a-distance" theory becomes invalid. In this instance the Third Law is, of course, still valid if applied layer-by- layer through the material, and momentum and energy are conserved by virtue of the wave propagation. It is such failure of action-at-a-distance theory that leads to recognition of the limited validity of the Third Law and finally gives primacy to the Law of Conservation of Momentum.

In the latter years of his life, Michael Faraday persistently asked questions as to whether or not there was a process in space that mediated electric and magnetic interactions: If one of two interacting charged particles is suddenly displaced, does a finite time interval elapse before the force on the second particle changes? Does a finite time interval elapse between the instant an electric current is initiated in a wire and the instant a neighboring compass needle begins to swing in response to the magnetic effect of the current? If a finite time interval does elapse, electric and magnetic effects cannot be action-at-a-distance. What happens in the intervening space?

To incorporate the possibility of the existence of finite time intervals, Faraday invented a model, a visualization completely transcending any direct sense experience — the famous concept of "lines of force" that stretched, contracted, spread apart, and pulled together, propagating electric and magnetic effects through evacuated space. All Faraday's attempts to measure a finite time interval failed; the technology of the time was not ready for so difficult an experiment. But James Clerk Maxwell took up Faraday's notion of lines of force, eventually creating field theory as we know it today. Starting with the apparent rigidity of tables and long rods, students can be led to some rudimentary insight into the failure of action-at-a-distance theories, how it is that primacy comes to be accorded to the conservation laws, and why field theory was invented, well before it becomes appropriate to set up and solve Maxwell's equations.

Research strongly suggests that the modes of thought described in this section help students synthesize, organize, and perceive unity in a wide range of apparently unrelated concepts and phenomena. This perspective must be cultivated in teachers before it can be successfully developed in our students.

6. Spiralling Back

An element referred to repeatedly in the preceding sections is the desirability of spiralling back so as to allow students to review or re- encounter important ideas and lines of reasoning in increasingly rich or sophisticated context. Following is one illustration of what this means:

The formula for centripetal acceleration of a particle moving at tangential velocity v in a circle of radius R

$$a_c = \frac{v^2}{R}$$

is usually derived initially in a kinematical treatment such as that in which one evaluates the acceleration associated with continual "falling" from the tangent line to the circle, or that in which one sketches the vector change in velocity between two locations of the particle along the circular arc and then evaluates the rate of change of the velocity as the time interval tends to zero.

A simple dynamical derivation is given by Newton in Proposition IV of Book I of the "*Principia*". Newton's derivation has been accorded very little attention, possibly because it is given entirely in words citing proportional relations and is unaccompanied either by a geometrical figure or by algebraic equations. (In the Scholium following several corollaries to the proposition, Newton acknowledges that "... by such propositions Mr. Huygens, in his excellent book, 'De Horologio Oscillatorio', has compared the force of gravity with the centrifugal forces of revolving bodies." Perhaps he did not play up the derivation because of Huygens's priority.)

Newton's proof, translated algebraically and geometrically, runs as follows (see Fig.1): Consider a particle of mass m moving at velocity v inside a rigid cylinder

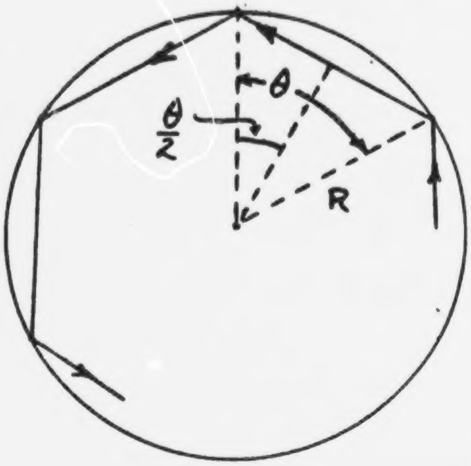

Fig. 1

Particle of mass m moves at velocity v along the sides of a polygon inscribed within a cylinder of radius R . The particle collides elastically with the walls of the cylinder at each vertex of the polygon.

of radius R. Suppose at first that the particle moves along the sides of a polygon inscribed in the cylinder, undergoing successive elastic reflections from the wall of the cylinder at each vertex of the polygon. The momentum change Δp at each collision is given by

$$\Delta p = 2mv \sin\frac{\theta}{2} \tag{6.1}$$

If there are n sides and vertices to the polygon, the total momentum change ΔP after one complete circuit is

$$\Delta P = n\left(2mv \sin\frac{\theta}{2}\right) \tag{6.2}$$

The time Δt to traverse one side of the polygon is given by

$$\Delta t = \frac{2R}{v} \sin\frac{\theta}{2} \tag{6.3}$$

and the period T for the complete circuit is

$$T = n\left(\frac{2R}{v} \sin\frac{\theta}{2}\right) \tag{6.4}$$

Since the average force $\overline{F}$ acting on the particle is given by the average rate of change of momentum (Second Law)

$$\overline{F} = \frac{\Delta P}{T}. \tag{6.5}$$

Letting n increase without limit, and putting (6.2) and (6.4) into (6.5), gives

$$\overline{F} = \frac{mv^2}{R} \tag{6.6}$$

It is interesting to note that no small angle approximation is involved and that the result is even valid for polygon with a finite number of sides.

This analysis has very substantial pedagogical value — not as a *substitute* for the earlier kinematical derivation but as a powerful *supplement*. It gives the opportunity to come back to the centripetal acceleration and centripetal force ideas from an entirely new point of view after some time has elapsed and after the momentum concept and its vector nature have been developed. The context is rich and conceptually significant: one makes use of the vector change of momentum in bouncing from the wall to obtain an important result and reinforce an earlier physical insight; the bouncing from the wall is not left as a seemingly sterile exercise in an end- of-chapter homework problem unconnected to other phenomena; a better foundation is laid for future use of such momentum change in kinetic theory.

The *order* in which the different derivations of centripetal force or acceleration are developed is probably far less important than the fact of spiralling back. If the momentum concepts were developed prior to the discussion of circular motion, one could give the above derivation first and then reinforce it by coming back to the kinematical treatments later.

7. Electricity

As pointed out in much of the research cited in the bibliography, students come to the study of Newtonian mechanics with deeply rooted *pre-* conceptions regarding force and motion. These preconceptions stem principally from intuitive perceptions, based on everyday kinesthetic experience with motion of familiar objects, and familiar vocabulary is forced to accord with these preconceptions.

Our concepts of electricity, however, are based on careful observation of phenomena that are not part of common kinesthetic experience and are built on the abstract models that derive from these observations. Since the majority of our curricular materials tend to assert the end results as though the basic electrical concepts were obvious and known to all, students come to the study of electricity with little or no concrete experience but with exposure to an extensive technical vocabulary that has not been based on careful or adequate operational definition. The consequence of such pedagogy is that the majority of students in introductory physics are imbued with a variety of verbal *mis*-conceptions that seriously impede the development of genuine understanding of electrostatic phenomena and of simple electrical circuits [Arons (1982); Fredette and Clement (1981); Cohen, Eylon, and Ganiel (1983); Steinberg and Fredette (1986)].

Although students may emerge from introductory physics courses with the capacity to solve routine textbook problems applying Coulomb's Law or Ohm's Law, investigation of their actual knowledge and understanding reveals that many students: (1) do not understand what is meant by "electrical charge", tending to regard it as some kind of substance; (2) have no operational idea of what is meant by "like" charges; (3) cannot cite the observations that lead us to believe there are only two kinds of electrical charge; (4) cannot describe observations indicating the mobility of electrical charge or cite experiments that lead to invention of the concepts of "conductor" and "insulator"; (5) cannot cite evidence that phenomena taking place in a system consisting of a voltaic battery and metal wires are in any way related to the phenomena observed with rubbed rods, pith balls, and electroscopes; (6) cannot cite experience leading to invention of the concepts of "electric circuit" and "resistance": (7) fail to understand that electrical charge is not "used up" in an electric circuit; (8) fail to have any valid understanding of "potential difference"; (9) do not understand what is meant by "short circuit"; (10) have no understanding of the energy transformations taking place in a simple dc circuit; (11) are unable to predict what will happen to the brightnesses of various bulbs, arranged in series-parallel configurations, when one bulb is removed from its socket or when a wire is connected so as to short two separate points in the configuration; (12) are unable to predict what will happen to the current at various points in such circuits or to the potential differences between various points.

in other words, the research shows that, regardless of ability to solve conventional end-of-chapter problems, many students (even in engineering- physics courses) have failed to develop significant phenomenological understanding of electrical concepts or electrical phenomena. Since most of our teachers, especially those working at pre-university levels, have been taught in the conventional manner, many of them emerge with at least some of the deficiencies cited above. They continue teaching the way they were taught and pass their deficiencies on to their students. It is clear that this feedback system requires significant alteration.

8. Geometrical Optics

The preceding section gives a specific illustration of how students fail to form underlying concepts and develop understanding of phenomena in electricity even though they (rather deceptively) seem to exhibit the ability to solve conventional problems. A completely analogous situation has been revealed in geometrical optics through the investigations of Goldberg and McDermott (1986).

The students interviewed by Goldberg and McDermott had successfully passed the work in geometrical optics in an engineering - physics course. They could solve conventional end-of-chapter problems on image formation by thin lenses, using the Gaussian lens equation, etc. The students, in the interview, were shown a simple arrangement in which the real image of a luminous object was projected on a screen by a converging lens.

The screen was then taken away without alteration in the object or lens positions, and the students were asked whether the image was still there and whether they would expect to be able to see it if they stood in some appropriate location. Many students believed the image disappeared in the absence of the screen and could not be seen without it.

The screen was then restored with the image visible upon it, and the students were asked what they would expect to see on the screen if the lens were removed without change in the object and screen positions. Many students indicated that they would then expect to see an erect, instead of an inverted, image of the object.

When the students were asked to describe in their own words what happened to the light between the object and the screen in the process of formation of the inverted image, many conveyed the idea that the image was "propagated" in erect orientation from the object to the lens, was inverted in the lens, and was then propagated, in its inverted orientation, from the lens to the screen.

When the students were asked what they would expect to happen on the screen if an opaque sheet of cardboard were placed so as to cover half of the lens, many said that they would expect to see half of the image.

Just as in the case of the electrical concepts, many of the students who had satisfactorily passed the formal instruction and who could solve conventional problems, revealed that they had virtually no understanding of the physical phenomena involved in image formation.

9. Implication for Teacher Training

The implications for teacher training of the researches summarized in the preceding sections are manifold and serious: Since most teachers are taught by means of existing curricular materials in the conventional manner, many of them emerge from this training with the same gaps and misconceptions revealed in the researches. Although the real, long term remedy for this problem resides in alteration of the curricular materials in general, and in reduction of the volume and pace at which subject matter is forced on students in introductory courses, it will probably be quite a long time before such reforms penetrate the entire educational structure. While the effort at long term reform for all students is under way, it is necessary to reach the teacher population directly in their pre-service education, in practicum experience, and in in-service workshops.

There are several levels of development of insight that must be cultivated in such endeavor:

(1) Teachers need to be led to review and re-examine subject matter that they believe they are familiar with from a deeper and more mature perspective than that conveyed in most introductory physics courses. They must be led to track down all of the "how do we know ... ? why do we believe ... ? what is the evidence for

... ?" questions that lie behind the concepts, laws, and models that they will be teaching. They must have sophisticated control of the processes and sequences of operational definition of all the concepts that are to be developed. They must be able to think phenomenologically in all areas of the subject matter and not just be able to solve the end-of-chapter problems. They must be adept at directing students to everyday phenomena that are related to the abstract schemes being developed in the classroom.

(2) Teachers must be made aware of the literature and of research results such as those described in this paper. Such awareness can be cultivated in the context of the retracing of conceptual structures suggested in (1) above.

(3) Through awareness of the research results and procedures, teachers should be helped to cultivate the capacity to observe their own students; to learn how to ask searching questions; to listen and to interpret student response without destroying the insights to be gained by prematurely answering the questions as soon as the students exhibit difficulties and misconceptions.

(4) Teachers must learn how to supplement the questions and problems in available curricular materials so as to direct the students to filling the gaps and overcoming the misconceptions revealed in the researches. It is worth noting that many of the questions and techniques used in the researches are directly transferable to this aspect of instruction, but good teachers must be able to generate appropriate sequences of their own.

(5) Teachers should be made aware of the need of spiralling back from later, richer context in all those areas in which students exhibit difficulty with concept formation and lines of reasoning (as illustrated in Section 6 above.) Students should also be exposed to Piaget's concept of "operations" (reversible lines of reasoning, whether concrete or formal) and should become sensitive to opportunities for altering problems simply by reversing the direction in which the reasoning is traversed |see Arons (1984a) for specific illustrations.| Such reversals are very helpful in leading students to master lines of reasoning.

(6) Since the real intellectual goals of any course are set not in the text or the presentation of the subject matter but in the *testing* on which grading and evaluation are based, teachers must be helped to develop the capacity to generate test questions that direct the students to full grasp and understanding rather than, as is presently largely the case, to superficial problem solving that is not accompanied by understanding.

10. Higher Order Thinking and Reasoning Skills

In addition to difficulties with specific concept formation such as those detailed in most of the researches that have been cited, the great majority of students have serious difficulty with what are currently being referred to as "higher order" intellectual skills. Among such skills are: (1) the capacity to initiate and pursue "how do we know ... ? why do we believe ... ?" questions on recognition that only end results are being asserted and that the underlying evidence is not being provided; (2) recognizing that information is missing or not being provided when such is the case in a particular problem or analysis; (3) recognizing when clear operational meaning has not been provided for a particular technical term and that the terminology cannot therefore be adequately understood; (4) recognizing when a conclusion regarding cause and effect cannot be reached because an essential variable has not been controlled; (5) being able to do hypothetico–deductive reasoning, i.e. given some situation, being able, in the abstract, to predict what will happen as a consequence of some alteration imposed on the system; (6) the capacity to explore, on one's own initiative, the consequences of the solution of a particular problem, including tracing out the implications for extreme or asymptotic cases; (7) the capacity and habit of checking one's thinking or results for internal consistency; (8) being able to make up probing questions and problems of one's own.

Although it takes a long time for all of us to develop mature command of such advanced intellectual modes, and although one can probably not expect students to develop very secure command prior to the later years of university education, the progress made by our students is far slower than it might be. If teachers had explicit awareness and more secure command of the higher order reasoning skills, they would be in a position to convey such awareness to their students. They could invoke such reasoning explicitly as opportunities arose in the subject matter, instead of just concentrating on the rudimentary concepts and lines of reasoning alone. In this way a higher intellectual synthesis could be provided and development of higher order skills accelerated.

Thus another, profoundly important, ingredient in teacher training would be the conscious development of an awareness of higher order reasoning skills and of the ability to enhance such skills in the students at judiciously designed levels and pace.

11. A Role for the Computer

One outcome of current research and observation over a wide range of different courses, made repeatedly in our group at the University of Washington, is that many students do not break through to command of a particular concept or sequence of reasoning unless they can be reached in a one-on-one dialog and led to articulate the story in their own words. Without such help, they make no progress in understanding and take refuge in memorization of problem-solving procedures that might harvest enough credit to pass the course. This is particularly true of pre-service and in-service elementary and secondary teachers. Specific examples of subject matter are: arithmetical reasoning using division; distinction between velocity and acceleration; interpreting position-time and velocity-time graphs in words and in motions executed by one's own hand; distinction between heat and temperature; forming and using the model of origin of phases of the moon; forming and using the models of current and resistance in simple dc circuits.

Such one-on-one dialog with a single student can easily take as long as twenty to thirty minutes or more. It is barely possible for teachers to do this in small classes, and it is out of the question in large ones. Here is a point at which modern technology can be of assistance. The coming-of-age of stand-alone microcomputers with graphical capability and of the interactive video disc offers the prospect of making one-on-one instructional dialog practicable in spite of numbers. The problem becomes one of writing effective dialogs that pull students over the early, most severe obstacles, and help put them on the way toward further learning, with decreasing dependence on such assistance.

The writing of effective dialogs, as well as the exploitation of the computer and the interactive video disc for doing appropriate laboratory experiments and for enhancing familiarity with a wide range of physical phenomena, will, of necessity, lean heavily on the results of research in cognitive development in general and teaching and learning of physics in particular. Not only must a skillful author have a broad awareness of what is being learned in general about cognitive development and patterns of logical reasoning, but he or she must also draw heavily on the detailed concept-by-concept student protocols. We ourselves very rarely make correct a priori conjectures about students' preconceptions, misconceptions, and linguistic difficulties. Yet, for a really effective computer dialog, the most important and difficult provisions an author must make are the ones that lead a student to rectify *incorrect* responses; it is easy to take care of the correct ones.

Given the rapidly increasing role of the computer in the schools, and given the amount of educational trash that is being propagated by many commercial publishing houses, it is essential to help teachers develop the ability to discriminate good computer materials from trash by giving them the kind of background outlined earlier in this paper. It is also highly desirable to develop as many teachers as possible to the point at which they can write competent computer materials for their own students and perhaps even contribute to a wider pool of such materials beyond their own classrooms.

(Space and time preclude more detailed discussion of the relation between the use of computers and the results of research on teaching and learning. There is a huge literature concerning the use of computers in physics teaching. Interested readers will find additional details and ramifications in Arons (1984d, 1986), Bork (1981), Taylor (1986) among others.)

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AN INSTRUCTIONAL STRATEGY
USING MICROCOMPUTERS FOR THE TEACHING OF MECHANICS

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The work we present is part of a national project, dealing with the use of computers in physics teaching, started in 1985 under the auspices and with the financial support of the Italian National Research Council (C.N.R.). The project engages a number of researchers in different Italian Universities and is aimed to the production of computer packages designed to improve the teaching and the learning of physics in high school.

The work carried out at the University of Pavia started from research findings (1,2,3,4) about the difficulties which often prevent students from reaching a fair understanding of elementary mechanics. Its aim is the development of a teaching strategy which could improve the learning of mechanics. On the basis of the results of the above mentioned researches and of our own experience, gained with undergraduate students in Physics, we tried an approach based on the integration of experimental activity with appropiate computer program.

THE STRATEGY

The strategy we developed is designed in such a way that interactive graphics programs are used by students jointlywith an intensive laboratory activity.

The strategy comprises three phases corresponding to different activities of the students:

1) observation and analysis of experiments which introduce the topic to be studied
2) running of computer simulations
3) carrying out laboratory experiment.

In phase 1 students look at simple experiments showing how the phenomenon, presented in a theoretical way in the lecture and in textbooks, has correspondence in the real world. These experiments must be designed in such a way that they direct the students' attention to the phenomenon rather than to the working of the experimental set-up. (The student should obtain, in this phase, only a kind of intuitive comprehension of the subject). Phase 1 could be enriched by the use of a good Physics film, that presents experiments that may be quite complex. The students should note differences and similarities among the apparatuses used in the classroom and those presented in the film. The comparison should allow them to become aware of practical constraints and limits of the observed experiments.

In phase 2 the students analyse computer simulations of the experiments considered in phase 1: the observed phenomena are the same, but now they can vary the value of the parameters in a wide range and obtain in a short time a view on a number of physical situations.

Phase 3 requires the personal involvement of students in laboratory work so that they can experience the difficulties of taking measurements in a real experimental situation and of drawing from them significant results. This experimental activity is carried out when the students are already familiar with the subject and have recognized the problems connectedwith it. In this way it should be easier for them to play an active role in the laboratory.

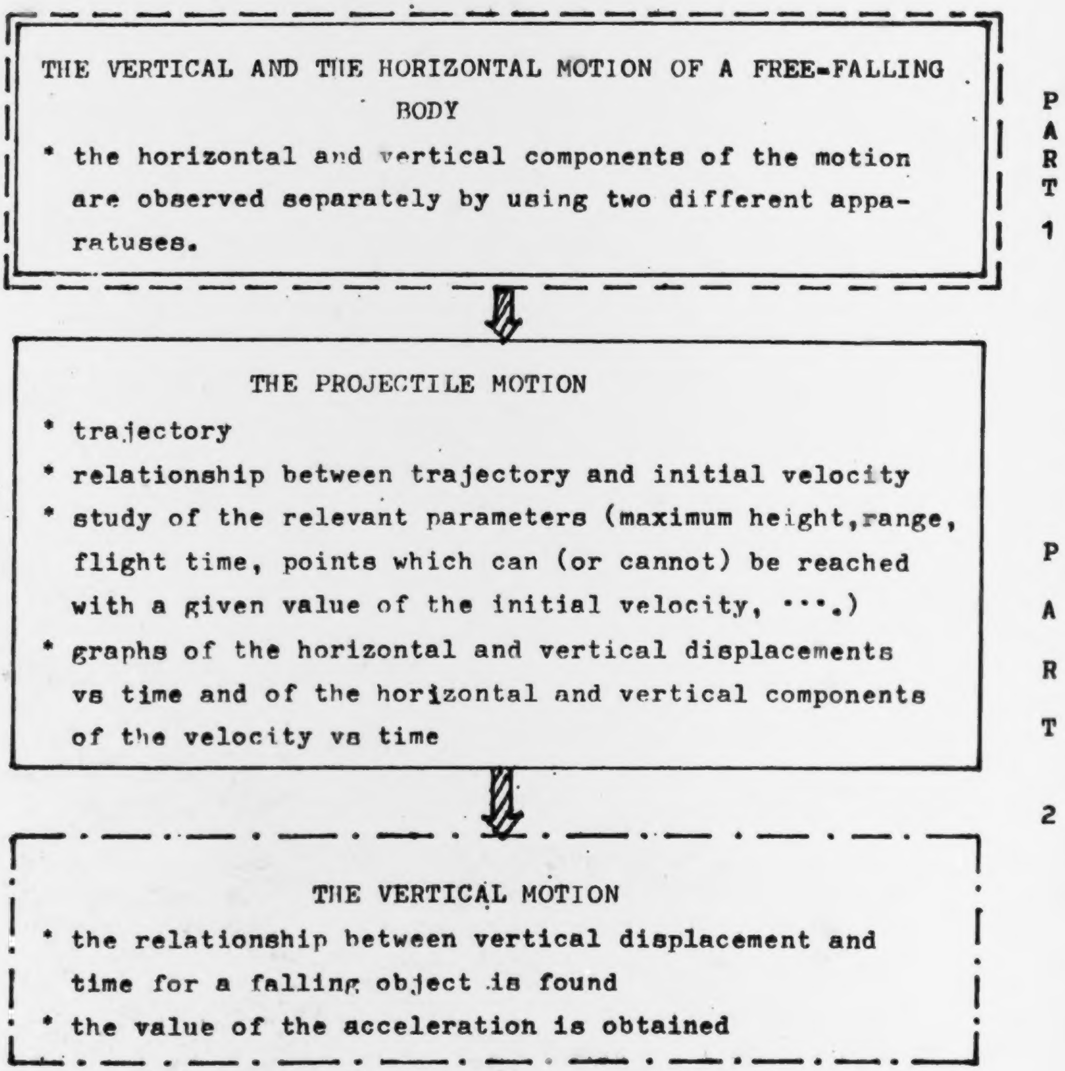
We called our strategy "packlab strategy" because the computer package employed in it must be produced and used in strict connection with the planned laboratory activity.

THE UNIT

Following the above mentioned guidelines we developed a unit for high school students dealing with the motion of free falling objects. We chose this topic, a classic one in mechanics, because a testing we had carried out with undergraduate students in Physics, by submitting them questions culled from the literature (5,6,7,), had showed that the topic is not well understood by the majority of the students although it is studied in every high school.

A detailed description of the unit will appear in an article in press on the magazine "Physics Education"; here we intend just to point out the main points of its structure. It consists of two parts: with the first one the students get aware of the fact that the vertical motion of a projectile is unaffected by its horizontal velocity; with the second part they study the trajectory of a projectile and measure the acceleration due to gravity. Figure 1 shows the structure of the unit.

THE STRUCTURE OF THE UNIT



THE VERTICAL AND THE HORIZONTAL MOTION OF A FREE-FALLING BODY

- the horizontal and vertical components of the motion are observed separately by using two different apparatuses.

THE PROJECTILE MOTION

- trajectory
- relationship between trajectory and initial velocity
- study of the relevant parameters (maximum height, range, flight time, points which can (or cannot) be reached with a given value of the initial velocity, ···.)
- graphs of the horizontal and vertical displacements vs time and of the horizontal and vertical components of the velocity vs time

THE VERTICAL MOTION

- the relationship between vertical displacement and time for a falling object is found
- the value of the acceleration is obtained

Fig. 1 (– – –observations, ——— simulations, —·—·—experiments)

The unit consists of:

- a diskette containing two computer programs, written in BASIC, running on Apple II and MS-DOS compatible personal computers
- a teacher guide

The guide contains suggestions for the classroom work, the listing of the programs enriched with detailed comments and instruction for building the experimental set-up.

CONCLUDING REMARKS

The strategy we have illustrated represents an attempt to ensure a close connection between experimental activity of students and use of computer simulations. We think that this connection is a crucial point when computer is introduced in the teaching of Physics.

In the case of high school students, for example, it is essential, in our opinion, that they are given the possibility of grasping the phenomenological aspect of Physics: so it is convenient to start with simple experiments and only after that to propose computer simulations. It would be very dangerous, in fact, if the presentation of a topic on thecomputer led to disregard the experimental activity, on the assumption that a well designed computer program may be a good substitute for it.

If we want to direct high school students towards a good knowledge of the fundamental concepts of Physics we must also provide them with the possibility of having "hands on" experience with experiments in order to personally test what a Physics experiment is and to understand the difficulties the experimental activity usually presents. If the use of computers is going to be in the future an alibi for avoiding involvement of students in the Physics laboratory we think that the teaching of Physics will be severely spoiled.

On the contrary, integration between the experimental work of the students and computer simulations, by extending the range of the exploration in a way otherwise impossible or very difficult to achieve in a common laboratory, could favour a deeper understanding of physical phenomena. A proper balance between these approaches should give the students a feeling of the complexity of reality, at the same time offering them a natural way to look for assumptions and simplifications which make possible to explore it. It will be teachers' task to find such a balance, depending on the particular subject they are treating, the age and maturity of their pupils, and finally their own ability to work with the material provided. Our experience in refresher courses for high school teachers together with observations made in testing our unit with future Physics teachers show that the latter is by no means a trivial problem.

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On The Role Of Demonstration Experiments In Middle School Physics Teaching

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Physics originates from experiments. From Archimedes' principle to relativity, any physics principle is connected with some specific experiments. That is to say without experiments, the origination of physics is impossible. Therefore in physics teaching, we must pass on physical concepts and principles to our students on the basis of experiments and, at the same time, develop their intelligence and competence. So we may well say that without physics experiments, there is no physics teaching, or at least, there is no successful physics teaching.

Generally speaking, experimental instruction is divided into student experiments and demonstration experiments. The goal of student experiments is to strengthen, deepen, expand knowledge learnt by the students in class, and to develop their skill of experiment through doing experiments by themselves on the basis of having learnt certain knowledge of physics before. Demonstration experiments, by the teacher, exhibit certain physical process in front of all students. This kind of experiments is usually for introducing new physical concepts, deducing new physical principles or verifying physical laws and rules. In short, through demonstration experiments, the teacher leads the students into a new physical world and explores the secret of this world along with them.

Demonstration experiments is a part of physics teaching and a good teaching method too. It would be safe to say that all concepts and principles in physics can be represented by demonstration experiments, thus creating a situation for the beginners, to hunt for the physics principles personally.

When demonstrating, the teacher should act according to normal procedure and use brief, exact, vivid and interesting language to enable all students to perceive this physical world. This is just what the famous proverb "seeing is believing" means. In the process of demonstration, the teacher should put more senses of students into action and lead them to observe, to think, and even to touch personally, thereby strengthening their impression and memory and tempering their thinking. In addition, we can make use of many teaching instruments such as overhead-projector, microprojector, stroboscope, closed-television, micro-computer and so on, to turn the small into the big, the static into the dynamic and vice versa, with sound and color, and simultaneously through five sense organs. In a word, demonstration experiments provide with plentiful perceptual knowledge, upgrade the students' interest in studying, cultivate their competence. We will elucidate these problems with some examples as follows.

1. To create physical situation to enrich students' perceptual knowledge

Physics is such a science that describes the motion of bodies in nature. It contains all kinds of knowledge pertaining to mechanics, thermodynamics, electricity, optics, atomic physics, knowledge about objects as large as heavenly bodies, and as tiny as atoms, knowledge about time from ancient times to future. For a middle school student or a college student, only a few daily life experiences, sensations, perceptions or representations are insufficient to study physics. So it is necessary for the teacher to set up a physical environment for students to study and grasp the meaning of a physical phenomenon. This role is mainly played by demonstration experiments.

Demonstration experiments are an important method to form perceptual knowledge. In physics teaching, perceptual knowledge from them is vivid, concrete, real and personal. For example, two disc dynamometers are used to show the students pressures on two stands due to the weight on a beam. In Fig.1, a weight of 1000 g. is placed at one-fifth of the beam's length, one nearer dynamometer shows a pressure of 800 g., while the farther one shows a pressure of 200 g.. This experiment makes the students realize the reason when two people carrying a weight with a pole why the one nearer the weight feels weightier than the other. The second example is that junior students often have difficulty in distingiushing the weight of liquid from the pressure caused by it. In such a case, we should set up a physi-

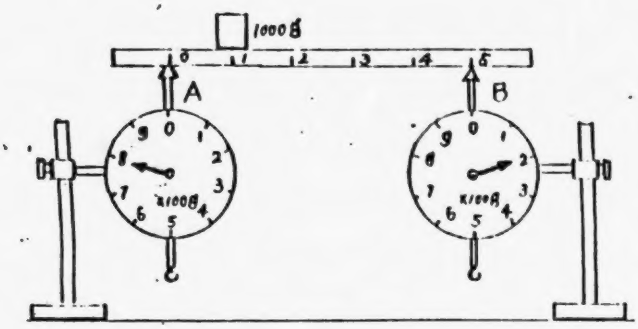


Fig. 1

cal environment to enable the students to acquire perceptual knowledge to differentiate these two concepts. The experiment shown in Fig. 2.

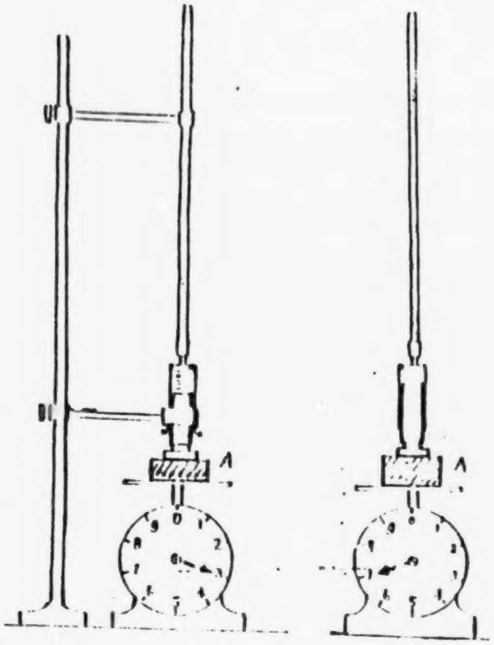


Fig. 2

illustrates this problem vividly. An injector filled with red liquid and connected with a thin glass tube, is installed on a stand. The liquid column inside the tube exerts pressure on the spring-balance through the piston and slab A. Let slab A lie eract or flat, thus changing the height of the column, while weight of the liquid remains unchanged. In this experiment, the reading of balance is 300 g. when slab lies flat, however, the reading will rise to 700 g. when it is eract. This indicates that the pressure of the liquid with constant weight will increase when the column of the liquid rises higher. This experiment makes a deep impression on the students. The above mentioned experiment, is carried out quantitatively instead of qualitatively to make impressions concrete and figurative.

In electricity and optics, more phenomona are not experienced by students in their daily life. It is more important to use demonstration experiments. Taking the problem of striding voltage for example, we can not experience it personally. We can only demonstrates its emergence, its damage and the physical protection against it. In fig.3. the ground is a foam sheet and A stands for high voltage wire fallen on the ground. A and B (B will earthed) ar connected to the two poles of an electrical machine respectively. Between A and B, there are some metal rings standing for equal polential lines. Let the potential difference between any two adjacent rings be equal. The distance between two adjacent rings gets larger, when they are farther away from A. In other words, the equal potential rings are closer in the neighborhood of A. Now we take a jumping lion as a body to get a shock. Its two fore legs and two hind legs are connected to the two poles of a neon indicator on the head of the lion respectively. The potential difference between its legs becomes higher and higher as it is moved toward A by the teache

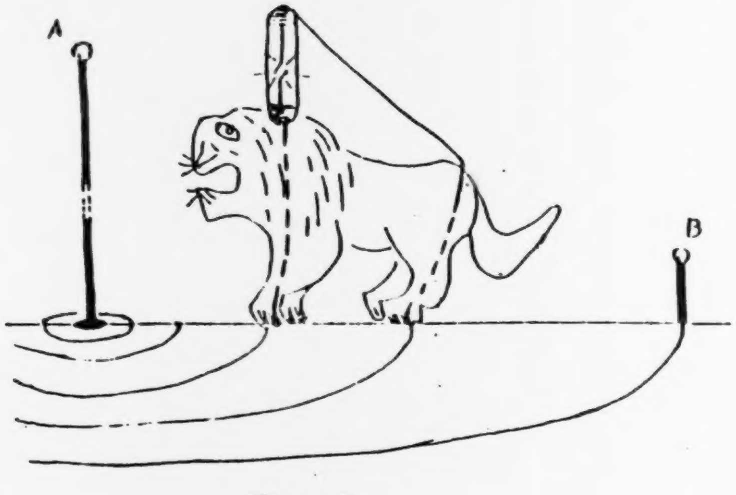


Fig. 3.

A, and finally is high enough for the indicator to glow. A junior student gets very interested on observing a movable "animal" in the demonstration. The lightning of the indicator will kindle inextinguishable sparks to his curiosity.

2. To attract attention and enhance interest of study

We know from psychology that attention is an important requirement in learning. Attention is also described as a door that everything entering the mind from outside must go through. This statement depicts the importance of attention. We see and hear things which we paid attention to. Otherwise we "look but see not, listen but hear not". No doubt, interest is a very principal factor in calling attention. What arouse one's interest? Generally speaking,strange and astonishing things play this role. In our daily life, magic and rope dancing often evoke our deep interest. We should consciously select demonstrations which are typical but exciting, astonishing but safe ones.

In the recoil demonstration, an ether flame-projecting wheel is far more brilliant than water recoil wheel. Fig. 4 shows the schematic structure of an ether flame-projecting wheel. The two ends of a three-way pipe are formed into sharp-pointed mouths and at right-angled to the horizontal tube. A test tube is filled with ether and closed with a rubber stopper, through which the pipe is inserted into the tube. A metal ball is put at the bottom of the tube to lower the center of gravity of the tube. When the tube is immersed in a flask with hot water, ether boils (boilling point

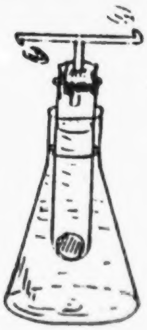


Fig. 4

35°C). The ether vapour rushes out from two mouthes. Then the tube begins to rotate. If the vapour is fired, the tube revolves much faster than before. This experiment is very wonderful. We use flame for the students to watch ether pouring out and to increase jet's speed. Thus a very deep and lasting impression is made on the students, and they get more lively knowledge of modern rocket. As mentioned above, a well-designed demonstration experiment can give the students an ever lasting impression. The ether recoil experiment is such a one!

In psychology, we call "attention" directly caused by interest as "unconscious attention" which is spontaneous and does not need willpower. In teaching we make use of unconscious attention to enable the students to gain perceptual knowledge in a relaxed and cheerful atmosphere. But perceptual knowledge has yet to be deepened. Therefore we teachers should lose no time to change unconscious attention into conscious attention. Conscious attention is dominated by will power. When the students are thirst for knowledge, the teacher should grasp this wish tightly and utilize their willpow to arrive at the teaching goal of a class. But the time ought not to be long-drawn-out for consious attention, otherwise the students may be tired. The teacher should apply two kinds of attention alternatively in teaching. That is to say, the teacher explains while demonstrating and demonstrates while explaining. In this way, a better result can be obtained in teaching.

3. To Cultivate Students Observing and Analyzing Ability and Develop Their Thinking

The process of students mastering knowledge is a complex mental process. We may divide various psychological activities into two series according to their cognitive functioning. One series is to stir up cognitive enthusiasm. Attention, interest, emotion, will and so on fall into this series. The other series is various psychological functions of the process of cognition itself. Such functions are sensation, consciousness, memory, imagination, thinking and so on. Experiments indicate that only if these various psychological activities of the two series actively participate in cognition and act coordinately can students master knowledge better. One important aspect of the teaching art is to handle and arouse the psychological activities of the students.

In order to make the students understand Archimedes' principle deeply, the experiment to verify Archimedes' principle may be arranged according to Fig.5. In order to demonstrate the phenomenon clearly, ~~first~~, we properly refit a balance, make the pointer and reading dial larger, use large plates instead of the small pans or scales, use cards to show the numbers of grams of the weights. A cylinder of 50 cm^3 with five graduations is made from a plastic tube, (the ends are closed with sealing wax). There is another measuring glass of 200 ml. which has bold marks indicating 50,100 and 150 ml. There is 100 ml water in the glass as shown in Fig. 5(a).

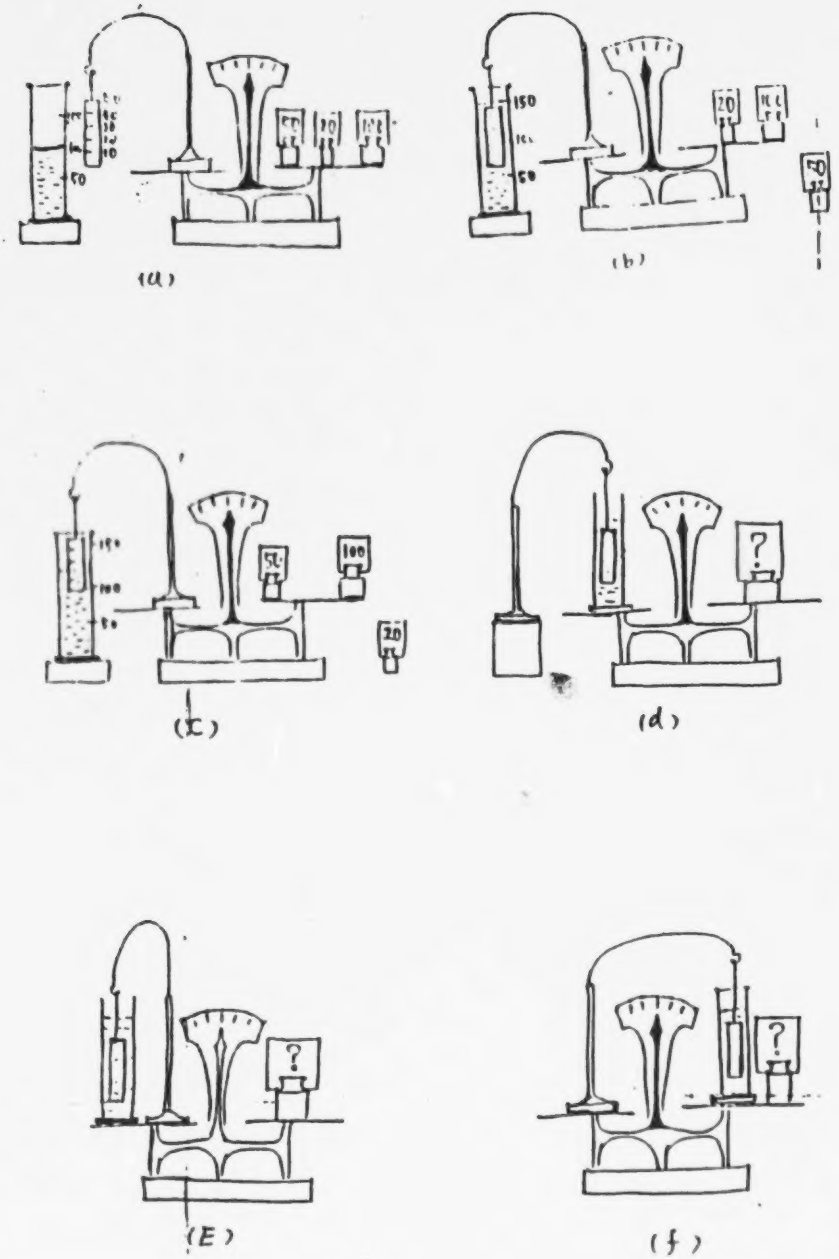
When making the experiment, we first verify Archimedes' principle with traditional method.

Submerge the cylinder into the water, then take one 50 grams off the plate, the balance will resume its equilibrium as shown in Fig. 5(b)

Then we make the experiment by partly submerging the cylinder into water (this step should be taken seriously and not at all be neglected). If the submerged part of the cylinder is 20 cm^3, the balance will resume its original state, when 20 grains were taken from the plate, as in in Fig. 5(c). Thus, we can draw the conclusion that the buoyancy of an object submerged in liquid is equal to the weight of the liquid displaced by the object.

On the basis of the students having mastered Archimedes' principle, in order to develop their observing and thinking abilities, we may make the following three experiments. First, exchange the positions of the measuring glass and the stand with the object in Fig. 5(d), adjust the balance to restore its equilibrium.If we then submerge the body into water, how should we change (add or subtract) the weights on the plate to keep the equilibrium state of the balance?

This experiment will enable the students to think actively. If the weight of the submerged object is decreased, how will the weight of the measuring glass (with the submerged cylinder in it) change? Will it become heavier or lighter? Through debating and experiment


150
100
50
20
100
50
20
?
?
?

(a) (b) (c) (d) (E) (f)

Fig. 5

observing, they find that the weight of mearsuring glass is increased and the weight increased of the glass is just equal to the weight decreased of the cylinder. What's all this about? At this point, the teacher may lead the students to observe the increase of height of liquid column inside the glass and analyse the corresponding increase of pressure on the bottom of the measuring glass. Finally and naturally they reach the conclusion that the weight of the glass is increased and the increased weight of the glass equals the pressure increased. Two more experiments can be made. In fig.5(e) both the cylinder and the measuring glass are put on the left plate. Adjust the balance until the two sides hang even. Immerse the cylinder in the water and ask:" how should the weights be changed?" In fig. 5(f) the object is put on the left plate and the measuring glass on the right plate. After the balance hangs even, immerse the cylinder in water, and ask how to change the weights to make the balance even.

We can see from the above five experiments that (b) and (c) are to generalize the Principle, and (d), (e) and (f) are to raise some thoughtful and inspiring questions based on the principle in order to train the students' observing and thinking abilities.

After students have studied the law of conservation of mechanical energy, we can demonstrate a rolling-up disc experiment. The units of the experiment are simple, a wooden wedge used as an incline and a flat disc, as shown in fig. 6. Drill a small hole at the edge of the disc and put a steel ball in it. Stop up the hole with a piece of wood to restore the original appearance of disc but mark the position of the hole for the teacher's later use.

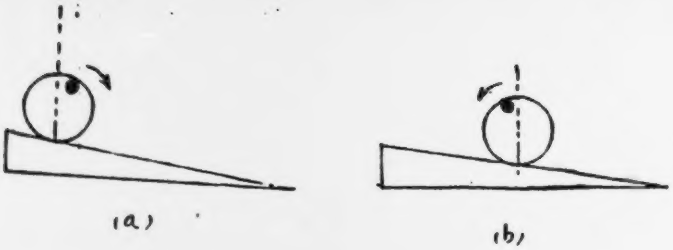

(a) (b)

Fig. 6

The experiment can be done in two steps. First put the disc at the top of the incline and be sure that the mark is on the right side of the vertical line. When the disc is released, it will roll down the incline just as the students expect because of the transformation of potential energy into kinetic energy. When they are taking this experiment for granted and thinking that there is nothing new, the teacher begins the second experiment shown in fig. 6(b). He places the disc in the middle of the incline and puts the mark on the left side of the vertical line. When it is released, it will "automatically" roll up the incline plane. This surprising fact, like a stone thrown into a quiet pond stirring up a series of waves in their mind. That's queer indeed! It went down only a momen ago. Why does it go upward now? Is it possible for the potential energy to increase at the same time for the kinetic energy to increase too? What a magic! Maybe some students think that there is a "ghost" in the disc. When the students are remaining puzzled afte pondering over and over again, the teacher should uncover its secre to eliminate their confusion and recover the authority of the law o conservation of mechanical energy. This is a natural and universal law and we can not contradict it even in playing magic.

In summary, we can make use of demonstration experiments to introduce new ideas as well as some unexpected questions. Usually,—

the latter are some paradoxes which are contrary to what the students think or are plausible. These questions force them to observe carefully the details of the experiments and the change of conditions. They will finally reach correct answers through analysis and synthesis. So their abstract thought is exercised greatly.

As mentioned above, we can realize the important role of demonstration experiments in creating physical situation, cultivating interest of study, expanding observation and thinking ability. Demonstration experiments have become important contents and effective teaching method. In Textbook of senior middle school, there a more than 130 demonstration experiments in the Physics Textbooks (Type B) and more than 150 demonstration experiments in the Physics Textbooks (Type A). Even in Physics Textbooks of Junior middle school, there are even more than 120 demonstration experiments. If every teacher organizes these experiments very well and gives full play to every of them, his work can certainly have better results.I is delightful that now many teachers, especially young teachers, ar grasping this essential link. They have achieved much in arousing the students' interest for physics and developing the students' intelligence and capability.

On the other hand, we should recognize that it is not easy to arrange, organize and perform demonstration experiments well. It costs the teacher a lot of time and painstaking efforts in preparin them. Even if the teaching aids are ready-made, we should be well-prepared to guarantee the sure success of experiments and gain bette results. But in many cases we do not have ready-made teaching aids, we can make the most of our own efforts to do everything possible an do it simply and thriftily. In fact, self-made aids have many advantages such as simple in structure, easy to make, lower in cost, durable in use, easy for students to make and operate. In many cases, self-made aids may play roles which ready-made,manufactured instruments could not. Therefore, having a number of ready-made instruments, we ought to encourage students to make aids on their own. In this way, the needs in teaching could be met and students' comprehension could be deepened and their skills could be developed. It would be safe to say that self-made aids are never fading flowers to arranging and organizing demonstration experiments.

To sum up, only if we fully realize the importance of demonstration experiments in teaching, do our best to bring into full play the effects of intruments at hand and encourage to the utmost the students to make as many self-made ,aids as possible, can we arrange, organize and perform demonstration experiments much better and foster much more talented constructive persons who are well-developed morally, intellectually, physically and aesthetically for the great cause of four modernizations of our country.

TEACHING PHYSICS IN DEVELOPING COUNTRIES AND THE ROLE OF LANGUAGE

R. KAMEL WASSEF, Physics Department, Faculty of Science
Cairo University.

Science in general and physics in particular, deals with the search of relations governing the laws of nature which exist independent of the searching individual. All scientific statement and laws made by us have one characteristic in common, namely, they might be true or false, adequate or inadequate. The reactio we get from any student individual taught a scientific principle depends in certain cases on the cultural and/or the religious state of mind of the individual. This effect is a little bit accentuated in Developing Countries because of the relative state of ignorance and the ethical trends of the ordinary individual. The scientific way of thinking has the important characteristic that the concepts which it uses to build up its coherent systems do not express emotions. For the scientist there is only "being" but no wishing, no good, no evil,etc. The scientist always seeks truth, he keeps always away from every thing voluntaristic or emotional. Incidentally, this trait is the result of a slow development, peculiar to modern Western thought.

In most developing Countries which suffered from imperialism of the western world, the hatred of the people to every thing related to the Imperialistic Countries induce, resention of scientific ideas and information coming from the west. Presently, there exists a high tide against using a non-mother tongue to educate students, despite the very large difficulty of lack of new terminology, lack of text books, lack of experienced teacher who can deal with science in the mother tongue of the Country. It should be here mentioned that in some Countries more than one mother tongue exists.

Besides to the people's sensitivity from Western Countries, the general ignorance and the strong ties that bind the human individual to religion and ethical view points present some resention to scientific facts, e.g., the evolution theory is eliminated from any science course because it contradicts with ethical directives. Any teacher who discusses such things with his students is considered as doing a criminal act and might be charged for that. From this trend that the student could very easily feel from the education system, the free scientific way of thinking becomes missing and in many cases distorted. This reflects on every daily incident in the society as long as logical thinking becomes irrelevant for ethics.

The Education System

A good education system is essencially based on four basic points, namely, the teacher, the material to be taught, the student, and the facility and demonstration means. For a developing Country, it is not suitable to waste so much time in teaching sophisticated topics that the student will never use in his every day life after his graduation, The scientific material contained in any course should be highly related to the need of the developing society. For a poor developing Country it is much better to graduate the students with a high technical ability to help in the development plans of the country, rather than to graduate them to act as scientific researchers in new scientific or theoretica fields that would have any real value to the home country itself.

In the past the social and technological development of the societies were slow, and the traditional education used to reproduce the society from generation to another. but early this century the rate of social development was too high for the education system to follow. Hence, a wide gap took place between technologically usable ideas at the homes of the individuals and the science ideas that are already taught in schools. Matching became missing between the least amount of scientific information needed to cope withm the wide spread technological applications.

The big jump in science and technology and the associated fast change in the social structure necessitated a drastic modific ionof the scientific contents of the different courses starting from the very early stage of preliminary school education. The aim of education in the modern school surely changed and the courses have to be redesigned in a way to add to the student's knowledge, besides the scientific information, how to accomodate with the new way of modern life which became basically controlled by science.

Accordingly, a new element in physics education should be introduced to bridge in the student's mind the relation between school physics and physics in every day life. This new concept requires from the teacher to care for both educational elements as well as the scientific context. It is not enough to teach the student the scientific principles without linking them with the gr number of tools and instruments he presently finds at home for every day use. The lack of this concept in physics teaching might bring us a disaster when the misuse of modern technology prevails. Pollution, as an outcome of such misuse, is an example. It is well known that the problem of pollution is seriously increasing, and unless drastic measures are taken , and the hasards of the new technology be taught to the youngesters, a gloomy end of mankind is unavoidable. The student should be made aware of the consequences of the new technology even before the scientific principle underlying this new technology is fully explained to him.

In view of the vast spreading of the scientific front, and the limited time of teaching, it is of vital importance for developing countries to select those fields and topics that might help in the development of the country. It is useless for a poor developing country to concentrate in the undergraduate courses on fields such as plasma, fusion, space physics, etc. Such highly sophisticated fields would never be of use in the near future of the graduate. It would be more appropriate to enrich the knowledge of the students in the fields which they are going to handle after their graduation.

Communicating physics

It is well known among students that because of the teacher, the students might like of dislike a particular course. The teacher formst the medium through which information is transfered to the students. If the medium is turbulent or unsteady for eacy launching of the information, the student will get lost. The teacher should have a good hold of the teaching material. Besides, the teaching language should be proper, particularly if teaching is not made with the mother tongue of the students and the teacher. A broken teaching language induces large uncertai ties and unavoidable distortions in the meaning and exact boundari of each term. This leads to poor understanding af the material.

The student who has to receive the information has got also his own problems. Year after year, while building up the scientific structure of the student, one should be sure that the students understood thoroughly the material given to them in basic courses. Little value could be attained from the process of evaluation by written examination since memorization usually substituted understanding.

Language and the quality of the teaching system.

It is clear that the understanding of the student depends on the teacher's ability to seed the information in the student's mind. However, it is not only the readiness of the student to receive the information in the class room that matters in the teaching system. A large proportion of the students listening to a science lecture given in non-mother tongue would miss a great deal of the lecture due to the difficulty of understanding the language rather than the scientific content. In order to understand more deeply the lecture, the student has to consult English texts written in Oxfordian language far from the reach of the student. Besides the difficulty of understanding the language of the text, its price might also be an obstacle for the poor student who cannot afford buying it. The pplicy of mass education in some countries rendered library services to be very limited. Few copies of a text book available in the library would'nt be sufficient for hundreds of students to read and to borrow.

In their attempt to account for the difficulty of the availability of the text books, some lecturers present to their students short lecture notes covering the important topics of the course. This process proved to be detrimental to the education system. The student, knowing that the note book will form the frame from which the examination questions will come, confines his studies to it without any trial to read further in any other reference book. At the end of the year the student might get a distinction mark, yet he is actually not fit to pass this level to a higher one.

Teaching Aids and Laboratories.

A poor developing country usually cannot afford spending money on teaching aids and good laboratories. The deficiency in laboratory practice motivated a strong trend towards theoretical aspects of science phenomena. This trend was even more activated by the technical ease with which theoretical topics are studied. In effect, it becomes a paper and pencil affair. Disregarding the importance of experimentation increased more the gap between physics in school and applied physics in society.

Handling scientific phenomena in a laboratory provides the student with some means of training to the scientific way of thinking withwhich be would bec able to assimilate and handle any problem in his future life as well as in his future work. A successful student would be able to make use of his scientific thinking not only in innovation and creativity in his future life, but also in acquiring a scientific attitude in his own life.

Improvement of teaching system in the Developing Countries.

In view of the above analysis, the following suggestions could be made to improve the teaching system to get better results.

1- Courses should be critically chosen and designed to be matched with the direct needs of the society.

2- Teaching should be done in the mother tongue of the students.

3 - Scientific terminology should be unified in any one language and should be critically translated.

4 - Writing scientific texts in the mother tongue for all levels should be encouraged and well paid.

5 - The educational efficiency of the staff members should be taken in consideration when evaluating a teacher for promotion.

6 - Scientific conferences in the local areas should be frequentl organized in order to keep physics education at a good level and upto the international level.

7 - A science Journal, published in the native language, would help the old graduates still working with science to keep in touch with the international literature and to inform them about recent advances in their fields.

8- Popular science should be cared of to supply the layman with information about the modern technology he is using.

Abstract Form

USING MICROCOMPUTER-BASED LABORATORIES TO TEACH PHYSICAL INTUITION

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In the United States science courses for both majors and non-majors have little carry-over to students' understanding of the larger physical world because they do little to connect coursework to students' everyday experience, to connect simple understandings to underlying principles, or to correct misconceptions based on everyday experience. Science laboratories were intended to provede the experiential base for such understanding, yet they too have remained divorced from students' real-world experience, offering, at best, formulaic applications of textbook materials rather than real explorations in the physical world.

Microcomputer-based laboratories (MBL) provide a tool which alters science pedagogy by enabling teaching to begin with students' direct experience of the familiar physical world. Learner-controlled explorations with easy-to-use tools give immediate feedback and encourage students to become active participants in a scientific process--to gather and analyze data, and to test and revise hypotheses. Students thus acquire an understanding of the scientific principles which underlie their experience; they develop a sound physical intuition and competence in using the symbol systems by which scientific understanding are expressed (e.g., graphs). Work done at TERC and Tufts University has shown that MBL tools are effective from middle school through college.

THE PRINCIPLE OF "COLOUR ANALYSIS AND MIXING APPARATUS"

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During teaching physics courses for the students major in chemistry biology and so on, we were often demanded to demonstrate and explain the principle of colour mixing. In the past, we used to demonstrate the phenomenon of colour mixing by using three light sources. Each of them produced a primary colour by using a corresponding colour filter. Then, the illuminating regions were overlapped to demonstrate this phenomenon. But in this method one had to adjust the relative intensity of the three primary colours in order to obtain white colour as the result of their mixing. This adjust is not only troublesome but also difficult to understand by the students, because most of the observers do not know the absorption properties of the filters.

Now, the colour television, colour photograph, and colour printing are widely used and the knowledge about colour mixing are widely required. Our instruction in optics must meet these needs. All these encourage us to revise the old method and improve it. With some painstakings and especially by the hint of the theory of θ -modulation in the optical information processing, we recommend the following design. (See Fig. 1.)

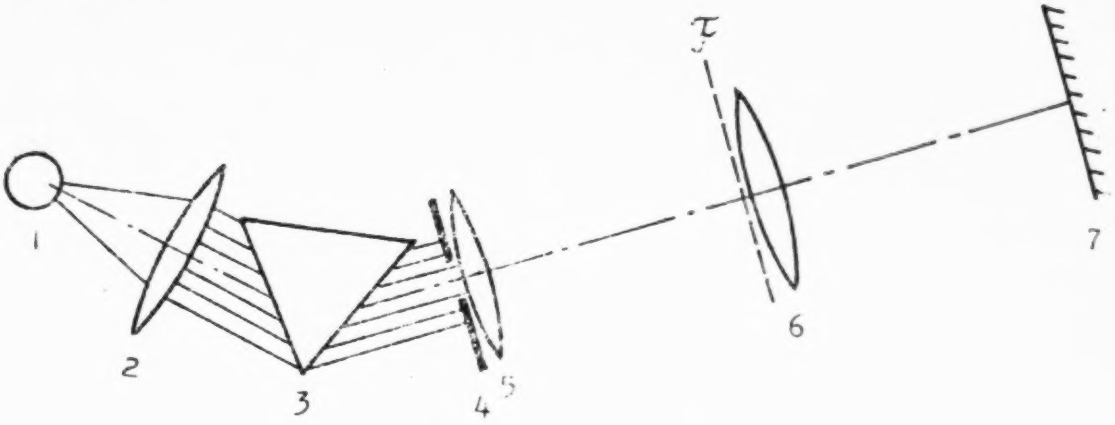

Fig. 1.

1. Point source S,
2. Collimating lens L_1,
3. Prism,
4. Circular diaphragm,
5. Convex lens L_2,
6. Projection lens L_3,
7. Screen.

The light from the point source S (white light) is collimated by the lens L_1 and then forms a beam of parallel light. After dispersed by the prism it illuminates the circular diaphragm and is collected by L_2. Finally we can find a spectrum of the light source at the focal plne of L_2. Let all the light rays of this spectrum pass through the lens L_3, thus the image of the circular diaphragm is formed on the screen.

Although the light emerged from the prism consists of many parallel beams with different directions serially located according to their wave length, there is still a small region nearby the prism in which, the beams with different wave lengths are superimposed. At every point of this region, the constituent of light of different wave length is the same as that of the light source. Therefore, the colour of light of this region is as white as the source. And we call this region "the white light region".

A key of our design is that: the "circular hole" of the circular diaphragm must be located in the white light region, so it must be white in colour. And because all the light rays passing through the "circular hole" reach to the screen with hardly any loss, it matches the illumination theory of lantern quite well, so the intensity distribution of "image" corresponds with that of the "object" ("circular hole") one by one. Therefore the image is white in colour.

Now, we may discuss the first demonstration: The phenomena of white light be analyzed into a spectrum and this spectrum be synthesized into white light again. The method is as follows: In the optical path as shown in Fig. 1., a piece of frosted glass plate is put in behind the "circular hole" and L_2, thus one can see a bright disc on the glass which is illuminated by the light coming from "circular hole". By moving this frosted glass plate toward $\mathscr{F}$ (the second focal plane of L_2), gradually, one can see that the bright disc is analyzed into spectrum gradually. Then we move the frosted glass plate toward L_3 and screen successively, the colour (spectrum) on the glass plate synthesize gradually into white again.

In order to perform the second demonstration based on the above experiment, we insert three wedge prisms on $\mathscr{F}$. Then, the left wedge deflects the spectrum of 4000–5000A to the right for an angle δ; the right wedge deflects the spectrum of the 6000–7000A to the left for an angle δ; the middle wedge deflects the spectrum of the 5000–6000A for an angle $1.73\,\delta$ upward. When the light of the spectrum passing through the wedges and L_3 arrives at the screen, three partially superimposed circular images with red, green, blue colour respectively will be formed (as shown in Fig.2)

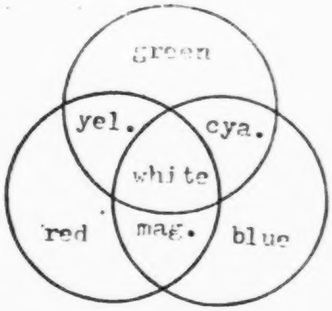

Fig.2.

The overlapped region of any two circular image will display a mixed colour according to the theory of additive synthesis. For example, the overlapped region of red and blue image displays a colour of magenta, the overlapped region of red and green image displays a colour of yellow, the overlapped region of blue and green image displays a colour of cyan. (The colour mixing of colour television obey the theory of additive synthesis).

This is the second demonstration experiment.

In order to emphasize some detail of above second demonstration experiment, one can perform the demonstration as follows.

1) For example, if only the part 6000-7000Å of the spectrum can transmit and the other parts on the focal plane F have been obstructed by a plate, then a circular image with red colour should just be displayed on the screen. It denotes that the colour effect of light with wave length of 6000-7000A is red.

2) Similarly, if only the part 5000-6000A of the spectrum can transmit and the other parts on the focal plane have been obstructed by a plate, then a circular image with green colour should just be displayed on the screen. It denotes that the colour effect of light with wave length of 5000-6000A is green.

3) Similarly, if only the part 4000-5000A of the spectrum can transmit and the other parts on the focal plane have been obstructed by a plate, then a circular image with blue colour should just be displayed on the screen. It denotes that the colour effect of light with wave length of 4000-5000A is blue.

4) For example, if the light with 4000-5000A wave length is obstructed by a plate and the other parts on the focal plane can transmit, the image on the screen will display a figure as Fig. 3.

By removing the plate, the blue colour will appear again (as Fig. 2). The region where yellow and blue colours have overlapped will display white colour. It denotes that yellow and blue colour form a pair of complementary colours.

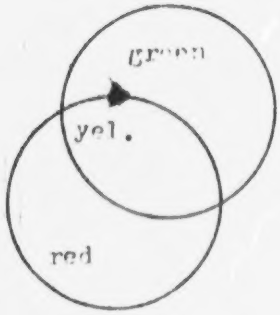

Fig. 3

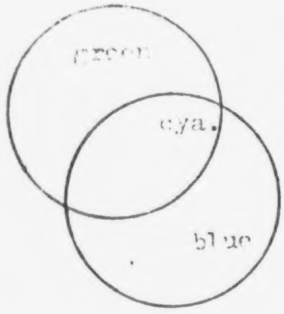

Fig. 4

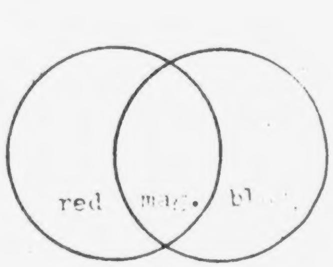

Fig. 5

5) Similarly, if the light with 6000-7000A wave length is obstructed by a plate and the other parts on the focal plane can transmit, the image on the screen will display a figure as Fig. 4.

By removing the plate, the red colour will appear again (as Fig. a). The region where red and cyan colours have overlapped will display white colour. It denotes that red and cyan form a pair of complementary colours.

6) If the light of 5000-6000A (green colour) is stopped by a plate the image will display as Fig. 5. By removing the plate, the green colour will appear again (as Fig.2). The region where green and magenta colours have overlapped will display white colour. It denotes that green and magenta form a pair of complementary colours.

It is noteworthy to point out that the designed apparatus has the following advantages: First, when it is taken to display an image as Fig. 2, the center of image always keeps white but does not need so much adjustment. The reason is that this region is overlapped by the three circular images, the light at every point in this region exactly contain all the same spectral constituents as those on plane and the relative intensities for each different constituent are also the same as those on plane. Therefore similarly as demonstration 1, they will synthesize into white colour. (Because the light emitted from "circular hole" is white, and all their spectral constituents keep their relative intensities unaltered when reaching the screen, it fulfils the principle of illumination. Hence they will be white in colour).

The second advantage of our apparatus is that the spectral constituent of the three primary colours we have taken (red, green, and blue) is obviously and easily to understand. (From the spectral distribution it can be realized that the adopted red, green, blue light consists of the light with 6000-7000A, 5000-6000A, 4000-5000A respectively). The disadvantage of the old method (that the observers hardly know the constituents of the three primary colours obtained by using colour filters) is successfully overcome.

The third advantage is: the wave length for the visible region is 4000-7000A. We divide it into three divisions: (4000-5000A, 5000-6000A, 6000-7000A). Each division corresponds to a primary colour, and the whole visible region corresponds to white colour. And then, naturally it is easy to explain why white light can be analysed into three primary colours and these three (with their original ratio of intensity) can remix into white colour. It must be point out that our method is merely one from many methods for selecting the three primary colours. According to the theory of colorimetry, the choice of the three primary colours is arbitrarily. But the three primary colours choosing in our method are more useful for the explanation of the theory of colour mixing.

When we have completed the design of the demonstration for colour synthesis according to additive theory, we study further the demonstration of colour synthesis according to subtractive theory. Our work in this stage mainly aims to find and prepare a set of complementary colour filters. This has also been successfully finished.

Demonstration 3:

There "wedge form prisms" are inserted on the plane of an optical path as shown in Fig. 1. Then placing the "yellow (complementary colour) filter" on the "circular hole", one may discover that the image figure on the screen alters from the Fig. 2. to Fig. 3. This phenomenon denotes that the "yellow filter" is really a filter that absorbes blue light. Similarly, when placing the "cyan (complementary colour) filter" on the "circular hole", one can discover that the image on the screen alters from Fig. 2 to Fig. 4. This phenomenon denotes that "cyan filter" is really a filter that absorbes red light. When placing the "magenta (complementary colour) filter" on the "circular hole", one can discover that Fig. 2 alters to Fig. 5. This phenomenon denotes that "magenta filter" is really a filter that absorbs green light.

This demonstration is really an experiment of absorption spectrum analysis. It tells us the absorption properties of the "complementary colour filters". (According to the method usually used in spectrum analysis one may observe the distribution of spectrum on plane, but for a demonstration experiment it is more convenient for the observer to display the phenomena on the screen.) Therefore we name our apparatus as "colour analysis and mixing apparatus".

Demonstration 4:

After understanding of the experiment 3, one can learn the "subtractive theory of colour synthesis" more easily. The method of demonstration is as follows. When two of the three complementary colour filters are superimposed on the "circular hole", one can see the mixed colour of them on the screen (optical set-up is the same as demonstration 1. 2. or 3)

For example, when the yellow and cyan filters are superimposed on the "circular hole", it will display a green circular image on the screen. It can be explained as: white light can be considered as the mixture of red, green, and blue primary colours, so when they pass through the two filters, the former one absorbs blue and the later absorbs red, therefore only the "green" colour left. This kind of colour mixing results from successive absorption of colour light, i.e. successive subtraction of some colour light. Therefore we call it "subtractive synthesis". Similarly the result of superimposition of "yellow (complementary colour)" and "magenta (complementary colour)" is "red", the result of superimposition of "cyan (complementary colour)" and "magenta (complementary colour)" is "blue".

(The colour synthesis of colour photograph and colour printing obey the theory of subtractive synthesis.)

Demonstration 5:

In order to demonstrate the phenomenon of colour synthesis according to the subtractive theory in a similar manner as that of experiment 2, we set up the optical apparatus as shown in Fig. 1. (there is no "wedge form prism" on the plane). Place the three "complementary colour filters" as Fig. 6. Then, one can see a similar figure (but reversed) on the screen.

figure (but reversed) on the screen.

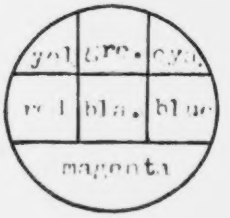

Fig. 6

In the region where two filters overlapped, according to the "subtractive theory" it will display the mixed colour red, green, blue. In the region where three filters overlapped, it will display a black colour. This is due to that the three complementary colour filters absorb the three primary colours respectively. As a whole, all the light has been absorbed.

In order to emphasize some detail of the phenomena, we remove one of the filters in Fig. 6. For example, when we remove the magenta filter and keep the "yellow filter" and "cyan filter" as shown in Fig. 7 one can see clearly that yellow mixed with cyan will produce "green" colour.

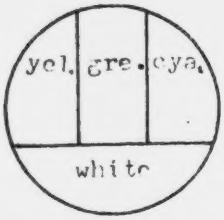

Fig. 7

Some explanation:

1. The optical arrangement of our apparatus as shown in Fig. 1 is really the combined optical arrangement of a spectrograph and a lanteen. Therefore it may be easy to set up our apparatus by using a spectrograph. We have completed our demonstration experiment in this manner successfully.

2. It is permitted that the dispersion element is a grating instead of a prism. But a large part of light energy will be lost.

If the light source in Fig. 1 is substituted by a slit illuminated by a light source with a condensing lens, the colour effect may be better. But the relative aperture of the condensing lens must be suitable for the relative aperture of lens L_1.

If the lens used is achromatic the effect may be better. However, a common un-achromatic lens is sufficient for most qualitative observations.

The lenses and prisms can not be coated with anti-reflection films because these films will distort the colour.

3. On the focal plane of L_2, if some special stops (or filters) are inserted, in order to control the transmittance for light of different wave length, one may obtain many different kinds of mixed colours and also complete some quantitative measurements.

4. This design has been applied for patent and put into production by a factory attached to our university.

Abstract Form

TEACHING ELECTRONICS THROUGH VIDEO

Professor M R Bhiday, Chairman, School of Communication Studies, University of Poona, Pune 411 007.

The rapid advances in electronics have necessitated change of strategy in teaching electronics at the undergraduate level. Teachers with knowledge of modern electronics are also not available easily.

It was, therefore, felt necessary to organise a course of electronics education using video cassette. Pre-production and Post-production research in the effectiveness of video cassettes for electronics education has been done for every cassette.

The results of this research are very encouraging. The student exposed to the conventional teacher alone; the video cassette alone; and the conventional teacher supported by the cassette sho improving results, in that order. A few programs with results will be presented in this paper.

THE DISCUSSION OF PHYSICAL THINKING AND CULTIVATION OF INTELLIGENCE AND ABILITY

Li Tianzeng, Department of Physics Southwestern Petroleum Institute, P.R.C.

"The task of science education is to teach students to create something new", especially in physical education. This paper has put forward five ability possessing physical characteristic through analysing the leading status of physics in natural science and human productive development, combining the author's experience of teaching several courses, guiding graduate papers and engaging in scientific research. These ability are: the ability of dimension analysis and order of magnitude analysis, the ability of diagram and diagram analysis, the ability of analysing physical system from both force and energy, the ability of abstracting physical model from objective physical system, and the ability of performing mathematical deduction for physical model. This paper also deals with the physical thinking and general significance of these ability and concrete measures through them into teaching links using a great deal of examples which the author has experienced. The author intends to explain the active and abundant physical thinking is the prerequisite of combining knowledge with intelligence and ability and creativity.

I

PHYSICS IS THE LEADING OF NATURAL SCIENCE

1. The significant findings in physics are the premiss of the third industrial revolution raised from using steam engine, electricity and atomic energy and the fourth industrical revolution characterized by electronic computer. Up to now, natural science has only experienced two eras i.e. classical theory based on Newton time-space view and quantum theory based on relativity time-space view. The third exciting era is pregnant in significant breakthrough of physics.

2. Due to the development of physics, people have enlarged and deepened their understanding of nature in such wide time, space and substance ranges as 10^{-23} sec. to 10^{18} sec., 10^{15} m to 10^{22} m, 10^{-31} kg to 10^{49} kg, more than 100 elements, 10^{3} isotopes and 10^{6} compunds. The enlargement and deepness of understanding are the results of physics providing with new technique, new material, new energy source and new means.

3. From the Middle Age "science" to 1543 Copernicus published "The theory of planetary motion" which just began a new era of modern science;

From Galileo who first created research method of observation and experiment to Cavendish's laboratory that created the glorious achievements among several generations;

From 1707 Newton's classical particle concept to 1923 De Bloglie who put forward "duality" concept;

From presenting quantum theory by Planck on October 19, 1900 to the time when he intended to "mediate" with classical theory but at last he had to give up the "mediate" work;

After 1905 Einstein had hoped there would be an experiment which could prove that his theory was wrong, to 1942 Fermi invented reactor according to Einstein's theory;

From classical mechanics having been developed for 300 years to Schrodinger who submitted to his first paper called quantum mechanics afterwards on January 27, 1926 ...

These extremely plentiful history of physics reflected extremely abundant physical thinking, physical theories and physical methods, which not only brought about the whole natural science involving many boundary sciences but may cultivate nimble ability of observation, precise ability of deduction and abstract ability of summary through studying physics the British as physicist Tyndall said 130 years ago.

II

SYSTEMATIZATION ON THEORY IS THE BASIS OF FLEXIBILITY ON METHODS

1. The systematization of contents in certain chapter should come from the systematization of this course.

In university physics, the concepts of force and energy have both profound physical meaning which distinguishes from different physical system according to different force and energy forms and true method meaning which may solve problems using either force's method or energy's method according to concrete conditions. Thus the concepts of force and energy as well as their calculations should be run through the whole teaching.

2. The systematization on theory in this course should be combined with the systematization on theory of this subject as well as possible.

The basic problem of electrostatics is to find "field" known "source". On the basis of university physics, the basic solution of Electrodynamics is to find the solution of Poisson's equation according to given boundary conitions. However, only when interface is a simple geometric surface can we find the solution in analysis form. Furthermore when the shape of interface is comparatively complex it is necessary to find solution through different conformal mapping. It has a tight connection with mathematics methods of physics courses.

3. We should completely describe methods based on theory.

To find thermodynamic functions although integral method is more complicated than characteristic function method, we should make a clear response to front and back: even though comparatively complicated integral can also be simplified unceasingly with theory deepening. After three deepening in theory all thermodynamic functions can be found only knowing equation of state and a heat capacitance datum under certain state.

4. During the course of teaching we should not only master both continuously developed theories but be able to move back to the theory developed already according to the basis, this is an efficient method mastering theory both systematically and deeply.

Under certain conditions: Lagrange's equation can be returned to Newton equation of motion; general relativity equation can be returned to Newton equation of motion and universal gravitation equation; collective model of nuclear can be returned to one-particle model; macrocanonical ensemble can be returned to microcanonical ensemble .... These are obvious examples. The advantages of these "return" are great for understanding their physical meaning deeply and grasping tight mathematical relation.

5. We intend to get distinct example summary from the combination of theory with method.

For example, I summarize briefly the main contents of thermodynamics as follows: one state equation; two kinds of heat capacitance and two kinds of methods finding thermodynamical function; three basic experimental laws; four equilibrium criterions; five thermodynamical functions. Thus in view of the theory, four equilibrium conditions are criterion which system is equilibrium state or not; the properties of equilibrium state are expressed by five thermodynamical functions; five thermodynamical functions can be found from state equation and heat capacitance; however all of these are based on three basic experimental laws. In view of the method, the methods finding thermodynamical function have characteristic function method and integral method.

In view of the above five statements: methods are based upon theory and will develop with theory; agile methods presuppose knowing well of systematic theory gradually; for actual problem, the combination of theory with method is just apparent creation.

III.

THE ABILITY OF LOGIC THOUGHT ON THEORY

The key of inspring intelligence and ability is that logic thinking of students should promoted from elementary to preliminay. During the course of teaching we should pay more attention to cultivating three logic thinking ability as follows:

1. The ability of comprehending abstract concepts and abstract theory.

As we know, "phase-space" is indeed an abstract concept in classical statistical physics, but we have sufficiently helped students to understand and master this concept by instructing some "geometrical relation" of that space, the relation of phase-space and subspace, partition function, corresponding relation of phase-space and quantum-state and emphasizing highly introduction of this concept as well as its significante, calculation and development of theory.

2. The ability of abstracting actural physical system as model of physics.

The model is a simplified physical system. In the simplicity we should notice three problems.

First, we are going to carry out main factors outstanding in the model. e.g., we consider molecule either as having translational kinetic energy or having inner partition function, as long as they don't contain the term of potential energy they are all "ideal" gas molecules.

Second, we must define model's proximity and its development. e.g., in real gas, although potential energy term has been considered, the function relation of molecular force is simplified. According to different simplicity, we have state equation of real gas in different forms. Among them the most conformable to actual equation is Onnes equation.

Third, we should combine the development of the same model in different area with their application as exactly as possible. As a matter of fact, classical harmonic vibrator (H.V.), quantum H.V., electromagnetic field collecting by in finite H.V., as well as liner relation in composition of wave and Laplacian operator suddeny appearance in Schrodinger's equation, they are all front and back development of H.V. and their applications.

3. The ability of mathematical deduction for physical models.

"Equilibrium state" and "equilibrium process" are all proximity for actual state and process of stystem. In order to determine statistic properties of equilibrium state, although three different outer conditions correspond to three different statistical ensembles, after determining statistical expressions of external force and internal energy, the main problem of classical statistical physics is mathematical deduction from calculation partition function.

From here we can also master another method judging that the results are correct or not —— we may not directly compare with experimental results, but we can compare with correct theory results which have been proved.

IV

COMPREHENSIVE ABILITY OF ANALYSIS ON METHOD

1. Deducing the same result using various methods and comparing these methods have distinct demonstrative significance for grasping theory and method systematically. These methods often disperse in different chapters of the same course or different courses. Hence we must have a well-thought-out plan and unceasingly extend.

The law of Maxwell velocity distribution can be deduced from the theory of quasi-independent subsystem and also deduced from H-theorem under equilibrium state; the formula of Planck heat-radiation can be derived from wave property of radiation field and also from particle property of radiation field .... It is apparent that opening up of the same question on different solustions can intensify efficiently the systimatical property in theory.

2. Method training for data processing of experiments is also an aspect that we should follow consciously in theoretical teaching.

We may train students with least-squares method for process equation of polytropic process and Cauchy dispersion formula. In general we may find temperature-heat capacitance data of some substances but we can also find internal energy differences within the range of the temperature using graphical integration. Even though we only explain individual example in teaching students benefit forever from the method study.

3. First of all, examination paper is for teacher to make do. High level's examination paper is such a paper that is not difficult but possesses extremely physical thinking. As is explained in the following two examples, we are making this effort.

(example 1) Explain thin-thick distribution conditions of Newton's ring using the following two methods.

a. find the derivative $\frac{dr_k}{dk}$;

b. find that area between adjacent two rings is equal or not.

(example 2) Two point charges q_1 and q_2 are r apart in vacuum.

a. Deduce Coulomb's law from Gauss theorem;

b. If Coulomb force is not inversely proportional to r^2, give an example to explain what kind of consequence would appear.

4. Dimension analysis should be definitely carried out in teaching.

We can determine from dimension analysis: The square of distance must be presented on denominator of expression of magnetic induction strength; The electric flux through any closed surface must be independent of size and shape of the surface; The wave velocity on chord wire must be directly proportional to the square root of tension and inversely proportional to the square root of mass density of line. There are typical examples using dimension analysis. But proportional coefficients in above formulae can only be determined by relative experiment or theory. Hence dimension analysis may not only judge that a complicated equation is correct or not in principle but also train comprehensively analytical ability in method through combining theory with practice.

Besides, it is necessary that we train students to write papers and give lectures about how to look up literature and how to translate. I have done this kind of work in the mechanical department and produced a good effect. I think it is an efficient method of comprehensive training.

V

ABILITY OF ANALYSIS OF MAGNITUDE ORDER

It is very important for students of physical department to analyse the order of magnitude. It possesses profound meaning both in theory and method.

1. Order of magnitude reflects deep contents of physics.

As we know, unit of energy of the atoms and molecules is in eV, the atomic nucleus is in MeV, the nucleon is in GeV. Besides people just realize "vacuum polarization" and "vacuum undulation" from the difference between g-factor and 2 is only 0.001. From this we can explain "Lamb shift" of hydrogen atom spectrum.

2. We can study changes in physical properties of system and physical laws from changes of magnitude order.

The most evident examples are: when wave length λ approximates to zero, the limit approximation of wave optics is geometrical optics; when pressure P approximates to zero, the limit approximation of real gas is idea gas; when motion velocity v approximates to zero, the limit approximation of relativity mechanics is Newton mechanics; when Planck constant h approximates to zero, the limit approximation of quantum physics is classical physics.

3. We may simplify calculation using analysis of magnitude order.

For example in r-radiation the probability of electric transition induced by charge changes is greater than for magnetic moment changes by a fator of 1001. Thus we can know through analysis, when we calculate the probability of r-radiation induced by electric transition we should consider mainly proton's transition in atomic nucleus.

Three points mentioned above may consider as theoretical significance of analysis of magnitude order.

It is apparent that we must analyze cause from physical model itself and systematic error when a theoretical result or experimental result is incorrect in order of magnitude; only when order of magnitude is correct are we going to do further approximate calculation of necessity or increase accuracy in measurement. This is just actual significance of analysis of magnitude order.

"The task of science education is to teach students to create something new", first of all physical teacher carrying on scientific physics education should possess the ability of creating something new and go ahead teaching and scientific research practice of creating something new.

About the author:

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The End

THE EXPLORATION OF TEACHING LAW OF CLASSICAL PHYSICAL OPTICS
—— THE PRACTICE OF TEACHING INNOVATION OF ENGINEERING PHYSICS OPTICS.

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Preface

Optics is a field that not only has a long history, but also has a favorable prosepct at the same time, as a physical branch, it is very practical and interesting, it is spocially suited to develop student's intellect and ability. For a long time there has been a very serious contradiction in the teaching of the engineering physical optics. At the present day the world's science and technology develop by leaps and bounds. Optics and optical engineering, as one field of the activest front of science and technology, have brought about a not-low-value effect on production and routine life, and become a powerer and powerer tool for human beings to explore and change nature. But in late years, there was little change in the teaching contents, plans and methods of engineering physical optics. These years our country's leaders have explicitly put forward that advanced education has to foster the talented people who can be suitable for three developing tendencies (the modern, world, and future), that is to say, to train and bring up the talented people who are rich in creative and initiative spirit, have wide and firm foundamental knowledge, and can meet the needs of the age.

Evidently the present state of teaching can not be suitable for the requirements. A lot of people are thinking over how to innovate in the physical education. Which contents should the engineering physical optics course indude? Which contents should be put emphasis on? How should we teach to get better results? Which measures must be taken to foster student's initiative spirit? And how to make passing on knowledge and training intellect and ability implement to every link of the teaching of engineering physical optics. As regards these questions. Since 1980 I have made some exploration and practice in my teaching process. Centering on the fundamental requirements I break through traditional limit and compile the optical teaching materials which are fit for the training aim of my institute; improve teaching methods and design a series of experiments after class.

I. A outlines of fundamental requirements.

In order to make it clear what extent the teaching contents of engineering physical optics should reach? How about the depth and breadth? I have made the following investigations.

1. Investigate which contents students learned and which experiments students made in the middle schools? How about the depth and breadth have the students mastered? In the light of these investigations I determine the low limit of which contents should be taught in the institute?

2. Investigate which requirements some specialties in my institute and some other universities have?

3. Survey the contents and the degrees of depth and breadth of some typical textbooks of engineering physical optics at home and abroad.

4. Survey the syllabus and contents of engineering physical optics of some countries.

5. Survey the contents and plan of my institute's mathematical class.

Referring to the investigations of the above 2,3,4 and 5, determine the upper limit of which contents should be taught.

6. Investigate the students whom I shall teach.

On the basis of these surveies and investigations I tentatively conceived a teaching syllabus and tried it out in the physical fast class of my institute. After achieving experiences I again tired it out in regular classes, and then according to the conditions of the studying and teaching effects I revised the previous conceptions.

On this foundation I tried to compile a teaching syllabus of engineering physical optics and put forward the fundamental requirements for optical teaching (please refer to Appendix 1)

II. A teaching material

In the light of the fundamental requirements I have compiled "teaching materials of clasical physical optics". There are the following characteristics compared with the textbooks of engineering physical optics used in our country at present.

1. The contents are much more difficult, and I omit the traditional geomatric optics which is usually included in foreign textbooks.

I consider what degrees of the depth and breadth of optical contents should not only be combined with the fostering aim of engineering students, but also should make it clear that my course is a basic course. As far as the combination with fostering aim is concerned, the contents which we teach should have an effect on students for a long time. We should lay a firm foundation for stadents to initiate new fields in the future, so it is one part of life-long education. On the other hand, our course is a basic course, it is different from the special course of optical specialty. Hence we can only deepen and widen on this basis to pave the way for succeeding courses, the contents must be fit for the specialties that the students will be engaged in aftor graduation and lay a foundation for students to teach themselves or electively study modern optics and the subjects relative to optics (Please refer to Appendix 1)

As for geometrical optics, it is induded in the textbooks of our country's middle schools at present. The contents are not very difficult. The students who don't major in optics need not make optical designs, but they must know how to make use of optical instruments. Hence the geometrical optical contents taught in middle schools are enough for students. However, in middle schools students didn't study the knowledge about optical instruments, hence in my teaching materials I add the chapter "optical instruments" to introduce the magnifying power and resolving power of optical instruments and simply introduce aberrations

2. I change the structure and order of usual textbooks of college physics, for instance, in polarizing part, at the begining I present natural light, linearly polarized light, elliptically polarized light and circularly polarized light, and then centering on the polarizing and analysing of linearly and circularly polarized light, I introduce Brewster's law, Malu's law and the birefringent features of anisotipic crystal. This order is closer to practical application which students are more interested in.

3. strengthen the requirements on mathematics.

Mathematics is an important tool in engaging in scientific reaserch and it is also the hight abstract and summary of scientific contents. Therefore we should let students learn to express physical contents with this tool. The optics of college physics is generally taught after students have finished advanced mathematics. So in my teaching material I apply mathematic expression as more as possible. The arrangement is also in favor of the traverse link of different specialties.

4. In order to give prominence to the thinking methods of analysing problems and stress physical concepts I omitted the complicated deriving process and laid special emphasis on the building of physical mould so as to enlighten and widen student's thinking and the ability to solve problems.

5. In proper chapters and sections I add several reading materials to widen student's intellectual outlook. In my teaching materials I also introduce some physical history and the exploring spirit of physicist to stimulate studnet's initiative spirit to scale the hights of science.

6. It takes about 22-24 teaching hours to teach the teaching materials I experimented in the Automatic Department of my institute (Please refer to Appendix 2)

III. Teaching

In order for students to learn thinking methods as well as theory knowledge, we should give heed to the following problems:

1. Explain the major problems explicitly and deeply.

For instance, while teaching the Young's double-slits interference, as a key problem of interference experiments we should clearly explain the following contents:

(1) experiment apparatus

(2) bright fringe, dim fringe, and coherent conditions

(3) light intensity distribution

(4) optical path length, optical path difference, and coherent conditions

(5) temporal cherence and spatial cherence.

As for Froshel's double-mirrors and Lloyd's mirror, it is enough to simply compare them with Young's double-slits.

2. We should place emphasis on the methods of analysing and solving problems and physical pictures and simply teach mathematic operation.

For example, on discussing the light intensity distribution of grating, I spend several minutes discussing the relations and differences between the diffraction of plane grating and single-slit diffraction the interference of multi-beam light, then I combine the formula of intensity distribution of single-slit diffraction with that of intensity distribution of the interference of multi-beam light to form the formula of the intensity distribution of plane grating. In this way concepts are manifest; physical pictures are distinct; complicated formulas being dissected, students understand it easily.

3. In order to stimulate students to think actively, each time I leave some questions for the students to think after class. These questions indude the widening and deepening of the contents in class, or the preparation for behind contents.

4. I properly introduce some physical history. In addition to passing on theory knowledge in class, I introduce some physical history and physicist's achievements to make students feel that scientists are also ordinary human beings, as long as they are adept at thinking and think diligently and are rigorous, honest and assiduous, it is possible to make their contribution to scientific development and human beings, thus stimulating student's enthusiasm for studying and creating.

IV. A series of experiments after class

Optics is a very practical and interesting subject, but in general, experimental class and demonstrating experiments can't reach the aim to develop student's intellect and ability. This is mainly because in the experimental class students only operate according to the teacher's arrangements and requirements, including experimental principles, operating steps and device selection, which can't arouse student's enthusiasm for thought. As to demonstrating experiments, generally the teachers themselves operate for fear that students should damage instruments. In my teaching materials although some efforts have been made to develop student's intellect and ability, those are only printed on paper. In order to train student's ability of analysing and solving problems independently, I think out a sevies of extracurricular experimental schemes. These experiments are simple, so I let students design and make them on their own, some of these experiments have been tried out.

1. Observe the reflection of plane glass and plane mirror

(1) Changing incident angle, observe the change of reflecting intensity of plane glass. Compare the reflecting intensity of plane mirror with that of plane glass

(2) Changing the number of plane glasses which are put together, observe the change of reflecting intensity, given the reflecting power of plane glass, calculate the needed number of plane glass.

2. Thin film interference

(1) according to the change of interference colors of oil film on the surface of water, estimate the thickness of oil film.

(2) firstly estimate the thickness of oil film, secondly calculate the incident wavelength.

3. Self-make Zone plate

(1) Given focal distance and incident wavelength, design and make circular Zone plate, rectangular and square Zone plate.

(2) observe the function of Zone plate

4. Locate the optical axis of quarter-wave plate

5. The polarizing and analysing of circularly polarized light

6. Observe man-made birefingence

Stretching plastic thin film longer, observe the interference of polarized light (observe the change of interference colors when thickness of film varies as drawing force). Learn how to self-make quarter wave plate

7. Observe the variation relations which wave plate varies as wavelength

8. Make circular polariscope

9. Observe rotatory phenomenon

10. Prove Brewster's law through the reflection of plate glass, learn how to measure the refracting power of opaque materials

11. Make holographic pictures

In general teachers put forward questions, and the phenomenon of possible or requiring appearance, and let students estimate by the knowledge they have learned.

On the basis of the estimation design experimental apparatus, put forth experimental conditions, and discuss and compare again. In the end the teacher provides materials, students make experiments, and analyse and discuss the appearing phenomena.

Through these experiments, we make students strengthen and widen the learned knowledge, train the student's ability of analysing and solving problems, develop student's intellect and ability, and strengthen the training of practical technical ability.

In a summary, some students say "Through these experiments, we have trained our technical ability, overcome the mood of fearing difficulties, and what is more, we have dismissed the thought that the peaks of scientific reaserch are too difficult to climb up, at present we often think of some inventions."

"After making these experiments, I feel the experiments in experimental textbooks are simpler...... The preference to optics stimulates me to study more theory and design more experiments. I surprisingly discover there are a lot of world's patent inventions using optical principles...... Athough the used principles of optics are not very sopnisticated, the effects are very good...... "

"These experiments increase the sense of interesting, make abstract physical law become the physical phenomena that are easy to be understand, widen thinking...... " we feel.

All these are only a preliminary trial. There is much room for improvement. Both the students and I consider it a good start and we should make more efforts.

Thanks

TUTORIAL TEACHING

Anthony W. Key, Department of Phys. , University of Toronto, Canada

This two-hour workshop will provide a self-referential exploration of small group teaching applicable to undergraduate instruction. The method will be experiential rather than didactic and will encourage members' interaction and participation. The duration and nature of the activities will be guided by the expressed interests of the participants.

Limited to 25 participants.

HOW TO CULTIVATE THE FACULTY OF THINKING OF UNDERGRADUATES IN TEACHING BASIC PHYSICS

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With the rapid development of the sciences of physics, in recent years, there appears to be a demand for improved method of teaching basic physics in classrooms. In order to enable the students to make use of their knowledge after graduation in keeping with the ever developing situation of the scientific world, it seems that particular importance should be given to the cultivation of the power of thought of the students. Albert Einstein once well said that independent thought and judgement were always the most important in the study of sciences. He pointed out that one who had basically grasped the theories of a science and made a practice of thinking out problems for himself would undoubtedly have a wider view of his subject and do better than those who were taught to know everything without their own aggressive thought of related problmes. My many years' experiences in teaching physics have fully convinced me of the truth of Einstein's view. Basic physics has a wide range of interrelated problems in itself. If the teaching program is made a series of massive complexities, it will impose a burden on the students in their attempt to learn things by rote. But, on the other hand, if the program is deliberately simplified or shortened as it may seem preferable, the students will have, narrowed observations of things with the result that their basic knowledge becomes limited. Both ways are inadvisable in the cultivation of power of thought of the students. So what we have to do, first of all, is to distinguish the "essentials" from the "non-essentials" that are mingled up as a whole in this branch of science. In this way we can have a program of teaching that consists of two parts—the essential part that calls for "intensive" study and the non-essential part that needs but "extensive" contact and perception. There is, of course, interrelations between these two parts. The students are hoped to be inspired by "essentials" to hunt for much more "non-essentials" by themselves. In my work-(A CONCISE TEXTBOOK OF MECHANICS) [2] the materials are grouped in two categories of different levels, each separate from the other: one level is for essential teaching the quintessential and concise, the other is for selected readings which include more references that can be read in extracurricular studies by students according to their different conditions and interests. It must be noted that quintessential teaching includes not only the scientific conclusions, but also the scientific processes and scientific methods.

The principal subjects must be selected for lecture in classroom and the origins,' developments, and relations of knowledge with the research methods, from which a scientific conclusion can be drawn, in order to make the students understand what the law of process are for "to obtain the knowledge" and can be in study, research and discovering. For example, in high schools the theoretical basis and application of the well-known Newton's laws have been explained, but in the university the understanding of Newton's laws must be deepened from the theory of knowledge and methodology and the students must be enlightened on study what are the historical background and the experimental bases leading to the formulation of the laws. The students are required to know how to use the specific mind methods (such as analysis, judgement, inference and abstraction) during deducing Newton's laws and to discuss whether there are any problems of "logical cycle" when the relative concepts are introduced.

The limitation of Newton's laws should be pointed out while the absolute space-time idea should be criticized. Further more the inevitable development from the classical Newton's mechancis to the modern relativistic mechanics should be reviewed. The students are required to sum up the typical methods which serve to answer the kinetic problems by using Newton's laws. In conformity with the above arrangements, some interesting problems such as the inertial system with Mach's principle and the time measurement with Zeno statement etc., are also interoduced. So combining the scientific nature and the logical process with the interst derived from knowledge, apart from the law of cognition of the students, they are enlivened to think and will take to seeking for knowledge spontaneously with the result that their abilities develop tremendously. My experiences in practice of teaching show that by such above ways the students' thought are activated. The students can ask and discuss some dominating questions with the teacher. Some students can read more reference materials and are anxious to try to publish their opinion in papers.

In books of modern physics there are many dialectical opinions and highly abstract ideas. However, a student who has just entered university tends not to think and reason in a logical way, they have intuition, imitation and analogy, instead of dialectical and abstract thought. It must be noted that the students must be encouraged to build up abilities to study with dialectical and abstract thought, even in his study of basic physics. For example, momentum and kinetic energy are the two basic concepts in physics and both of them relate to mass and velocity. The students always at a loss to know which of the two is the real criterion for measurement in mechanical motions. This problem has been discussed by many famous scientists for more than forty years in the last century. After the historical background has been simply introduced, I would like to emphasize that Engels' opinion about two kinds of motion-measurement [3] is valuable and put forward my personal view as to how to correctly understand the meanings of momentum and kinetic energy in terms of dialectical senses with respect to the forms of kinetic transmition. On the basis of above, we let the students understand why momentum is a vector which has a connection with the time intergrated effect of force and kinetic energy is a scalar which has a connection with the space-intergrated effect of force. Further more, we should point out that in Newtonian machanics momentum and kinetic energy are two different kinds of reliances for measuring the motion of an object, but in the relativistic condition, the energy described in one reference system is related not only to the energy in another reference system but also to its momentum, that is a four-dimensional vector, thus a unified momentum energy, can be obtained [4]. This way enables the students to know primarily that they should study problems of physics by means of dialectical thought.

On the other hand, it must also be noted that students should have the ability of setting up a model of physical illustration by abstracting rules from the complicated physical phenomena. This is a basic method for physical research and all particles, ideal rigid body, ideal fluid, point charge, molecular current, molecular model of ideal gas, nuclear model of atom, etc. are physical abstract models. We always believe that a student can hardly work out a problem of physics if he is unable to formulate a correct physical abstract. Therefore, we make it a point that students be advised to make analysis and abstract the physical problems from their everyday activities. For example, an interesting question is why a man jumps to riverbank from a small boat with greater difficulty than from a big ship? The students often get entangled in their scrupulous thought of the jumping action in their discussion. However, so long as the man, the boat and the ship are treated as particles and the condition in which the man jumps to the riverbank successfully is treated as a requirement for certain horizontal velocity of the man's action in relation to the riverbank, the two cases of the systems that consisting of the man and the boat (or the ship) are analysed.

According to conservation of the horizontal momentum of the system, the velocity of the ship v_1 is smaller than the velocity of the boat v_2, because the ship's mass m_1 is larger than the boat's m_2. Then, according to the law of kinetic energy, it is but natural that the man should jump with greater difficulty from a small boat than from a big ship, because he must exert a greater effort to jump from the boat than from the ship.

Another problem is about the rotational inertia and angular momentum, which the students seem to have no less trouble to grasp. So we get the students to analyze the case of a swing, which is only too common an apparatus to them. In the beginning, the students can only get their intuitive impression that people must stand up when the swing platform is swung down to the lowest point and then their knees would bend low to gather strength when the platform is swung up to the highest point of the swinging motion. The student can not analyze the mechanical principls.

Then I showed them a simple demonstration: a little ball fastened to a long rope was hung up over a pulley. When the ball swung just over the equilibrium position it was raised up by pulling the rope and when the ball was up to the highest point on either side it was let down by loosening the rope. Thus the ball would swing up higher and higher. Then I asked the students how to abstract that the man who is on the swinging platform is a particle and the motion of the man as the change of rotational inertia about a fixed axis, and how to analyse as to when the angular momentum is conservative and when the mechanical energy is conservative. After the students come to understand why the mechanical energy increases with the raising movement of the swing, the theoretical calculations should be done according to the mechanical formulas. Besides, the conversation of angular momentum can have effect on other phenomena, such as the pirouette of ballet dances, the change of velocity in which the earth revolves round the sun, even the change of relative period of a star in which it collapses into a neutron star. In order to enable the students to transfer their intuitive impression into physical abstract, I made a video tape respecting the above as a demonstration in my teaching.

Somebody thinks that students must do a lot of homework to build up their abilities. As this may make the students tired out from too much homework and they may not have sufficient time to study the basic theory and to consult some needed reference materials, they take to mechanically copying the answers to their problems in some books available.

It seems that the students have done much enough homework, yet they do not seem to have conquered their difficulties. I do not mean that the students' homework is of no importance for the good of the students, but motivation or suggestive problems must be carefully chosen, especially those typical problems in which there are some doubtful points or matters inviting arguments. The tutorial procedure must be suggestive and not be of the sort of working out problems mechanically.

In order to cultivate the faculty of thinking of the students, the traditional-type of teaching tactics in physics must be renewed and the students should be allowed to have more time to keep up readings in the library as extracurricular studies. Recently, many of the lower-grade students in universities think that to attend lectures in classroom is the only way to learn. They don't realize the importance to study independently out of classroom. As a result some university students have excellent records of examinations but their practical abilities are not so good. Some students are handicapped by lacking the ability to think independently and study with active imaginations. They seem to have little wish for valued acquisitions. These shortcomings have been the result of the above mentioned traditional type of teaching tactics.

In my practice, the infiltration type of teaching, suggested by professor Yang Zhenning [5], has been adopted. The idea of such a teaching method, in which the students are allowed to study extensively for themselves, is to lead the students to understand much more things that are valuable for their future career. The development of the most advanced theories of physics of today is being introduced in my lectures so that the door to modern physics is opened to the students who are used to appreciating classical physics.

Upon the suggestion made by Professor Qian Weichang [6], I decided to reduce the bulk of the teaching stuff used in the classroom, but at the same time a large amount of varied extra-curricular studies are arranged, such as common lecture of reading, seminar about relative natural science, demonstrative experiments, and video-recording, etc...

To cultivate the faculty of thinking the students is like a relay process with the nature of determined adoption. We hope that a good start has been visualised in renovation of our teaching method in universities. A greater amount of work in this respect is to be done.

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AN APPROACH TO THE EVALUATION ON THE TEACHING QUALITY OF THE LECTURES ON UNIVERSITY PHYSICS OF HIGHER ENGINEERING EDUCATIONAL INSTITUTION

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ABSTRACT

For setting up the evaluation creteria on the teaching quality of the lectures on University physics, this paper puts forward the following main points:

The evaluated objects are to be the college or university and the teaching-research group of this course concerned.

The content of evaluation consists of three grand items: the quality of student cultivation, the teaching administering process and the teaching conditions; under each grand item are set up a certain number of detailed items.

The evaluation period is set as three years, with the current year of the main concern and the other two preceding years also appropriately taken into account.

The evaluation methods: adopting both scores and comments, through which the achievements should be ascertained and the shortcomings should be pointed out so as to enable the evaluated units to have a clear orientation of efforts, thus benefiting the further raising of the teaching quality of the lectures on University physics.

Evaluation grades are supposed to be : Excellent, Good, Qualified, and Unqualified for the time being.

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The lectures on university Physics is one of the most important basic courses in an engineering college, the teaching quality of which has a considerable effect on that of basic courses as a whole. The objective and scientific evaluation on the teaching level, the achievement and the existing problems of this course is very significant for further raising the teaching quality of it. This paper just attempts to make an approach to the standard of evaluation on the teaching quality of that course.

The teaching quality of the lectures on university physics is relevant not only to the teaching level of the teachers of the teaching-research group but also to the study style of the concerned college or university as well as the teaching facilities provided for that course by the concerned college or university. Hence, the objects of evaluation should be the college, the relevant teaching-research group and the students who have studied or are studying that course.

The content of the evaluation consists of three aspects: the evaluation on the learning quality of the students, the evaluation on the teaching process carried out and the evaluation on the teaching conditions provided for that course by the college (such as the teachers status, the illustrating experiments and the reference materials), i.e. on the learning quality, on the teaching process and on the teaching conditions. To avoid judging only by a single event or a short period of time, we suggest that a period of three consecutive years be taken as the evaluation period, with the current year to be the main concern and the two preceding years also taken into account.

For making clear the basic situation of the three evaluations and the orientation of efforts, it is suggested that each kind of evaluation should be scored and commented individually without adding the three individual scores into a total sum. And in view of the conditions of individual colleges or universities being not completely reciprocal, it is advisable not to arrange the relevant colleges or universities in order of quality level.

I. Grades of Evaluation Level

Excellent: (1) the training quality of the students is higher; (2) the level of the teachers higher; (3) both teaching level and scientific levle better; (4) the teaching conditions good. Both (2) and (3) are scored 85 marks.

Good: (1) the training quality of the students is good; (2) the levle of the teachers better; and (3) either the teaching level or the scientific research level better, but the level of the remaining one less good. Both (2) and (3) are scored between 75 and 85 marks.

Pass: (1) the training quality of the students conforms with the basic requirement; (2) the level of the teachers mediocre; (3) the teaching level fairly good, the scientific research level less good. Both (2) and (3) are scored between 60 and 75 marks.

Unqualified: (1) the training quality of the students does not conform with the basic requirement; (2) the levle of the teachers less good; and (3) the scientific research underdeveloped, and the teaching unqualified. Both (2) and (3) are scored below 60 marks.

II. Three Concrete Contents of Evaluation

I. Evaluation of the training quality of the students (with written comments).

I-1 The level of the mastery of the fundamental concepts, fundamental knowledge and fundamental techniques of calculation of Engineering College Physics by the students:

1) Selective survey of the terminal examination records of all the semesters of the three consecutive years: Check whether the quality of the problems of examination are up to the requirement and the distribution of the records is rational.

2) Selective test records average: Test selectively 10% of the students and calculate the absolute average scores and the relative average scores (i.e. the ratio of the selective test average scores to the entrance examination average scores). The contents of the selective test paper consists of two parts: basic requirement and extended requirement, the scores of the two parts needing not to be added together, with the basic part to be of the major concern and the extended

tended part only for reference. The scores are on the percentage basis.

I-2 The level of the ability of students in applying their knowledge of physics:

1) Select one class of students to investigate their respective self-study abilities.

2) The average number of students having published papers relevant to Engineering College Physics during the evaluation period:

$$\frac{\sum_i \text{number of papers } N_i \text{ published in journal } i \times \text{weight } \rho_i \text{ of the journal } i}{\text{Total number of students studying physics during the past three years}}$$

3) The status of prize-awarding student's in the physics competition at a provincial level or a municipal level:

$$\frac{\sum_i \text{number of students } N_i \text{ of the prize } i \text{ awarded} \times \text{grade of the prize } i \text{ awarded}}{\text{Total number of students studying physics during the past three years}}$$

4) The status of participation in the extracurricular physics-interested groups.

5) The evaluation of the successive courses on the learning quality of physics of the students.

Methodology: First, the evaluated unit makes a self-introduction and provides the necessary data and materials for evaluation; secondly, the selective tests, investigation meetings, etc. are conducted.

Conclusion: According to the standard or criterion of evaluation, a comprehensive comment is to be worked out.

II. Evaluation of the teaching process (100 marks):

II-3 Teaching Process (40 marks);

1. Boefore class: (10 marks): 4 items: whether the text-book of College Physics is adopted;

whether there is a Teaching Program conforming to the basic teaching requirement; whether has been set a teaching calendar; whether the relevant exercises are complete.
The 4 items are complete and well prepared.
The first 3 items are complete and moderately prepared.
The latter 3 items are basically unqualified.

2. In class (20 marks): Primarily evaluate whether the teaching style of the teacher is strict and conscientious, the quality of teaching, and the learning style and learning quality (including comprehension quality in class).

   Method: The members of the Evaluation Group selectively attend and examine the lectures of 1/3-1/5 teachers and then fill in the form of Lecture Evaluation (see the attached table 2). Meanwhile organize the relevant students to fill in the form of Lecture Investigation (see the attached table 2). Finally make statistics separately and give a score of impression.

3. After Class (10 marks): Primarily check the integrity of other teaching links such as coaching, homework correction, inquiry and testing, and the administering and performance of the links, and give a score of impression separately:
   All links are complete and conducted well.
   All links are complete but conducted moderately.
   The links are incomplete and conducted less well.

II-4 Teaching trsearch process (40 marks):

1. Student-oriented teaching reform research (20 marks): Such as the points and coverage surface of teaching reform including the reform of teaching system, methods, and content, the guidance of students' self-study, and the organization of extracurricular scientific-technic groups or physics-interested groups. Check the status of the above mentioned.

2. Teacher-oriented teaching research (20 marks): Such as the studies on teaching materials published at home or abroad, and on teaching methodology, and the academic discussion activities. Two comparable indicators should be worked out:

1) The planning, times and the actual performance of the teaching methodology research (10 marks):
   - Having plans with relevant research projects which are well carried out.
   - Having plans with relevant research projects which are carried out less well.
   - No plan and research project at all, such research basically having yet developed.

2) The number of per person papers of teaching research published or read out in a science conference (10 marks):

Number of per person papers published

$$= \frac{\sum_i \text{number of papers } N_i \text{ published in journal } i \times \text{weight of journal } i}{\text{total number of teachers}}$$

Number of per person papers read out

$$= \frac{\sum_i \text{number of paper read out } N_i \text{ in conference} \times \text{weight of conference}}{\text{total number of teachers}}$$

Suggestion of weight setting:

Let the weight of journals or conference college level and the equivalent journals or conference = 1, then the weight of the journals or conference at state level=2-3, and the weight of journals or conference at international level should be a bit greater depending on the specific context.

- The number of the annual per person papers published and read out is more than 0.25 (any paper re-published and re-read out can only be counted once); the same way applied to the counting below).
- The number of the annual per person papers is between 0.1 and 0.25.
- The number of the annual per person papers is below 0.1.

II-5 The quality of the teaching management system (20 marks):

It refers to whether have been established the system of teacher engagement, the system of new teacher cultivation, the system of teaching inspection and lecture examined on the spot, the system of the checking of the student disciplines and the student academic performance, etc.

All the systems are perfect and conscientiously carried out.
All the systems are established but moderately carried out.
The systems are inperfect and not carried out well.

III. Evaluation of teaching conditions (100 marks):

III-6 The number and composition of teachers (20 marks):

1) The ratio of the number of the students simultaneously at school to the number of the physics teachers within the authorized size should be 50:1 - 60:1 which is taken as a standard (the number of foreign students or non-college-level students are converted into that of college students) (10 marks):

Basically conforming to the standard.
The difference from the standard being less than 30%.
The difference from the standard being greater than 30%.

2) Whether the composition of jobs is reasonable (10 marks):

The percentage of the number of professors and associate professors to the number of teachers engaged in the teaching of the lectures on University Physics should be no less than the specified average percentage of the college or university concerned.
That being 50% less than the average peroentage.
That being less than the average percentage by greater than 50%.

III-7 The percentage of the number of professors and associate professors giving lectures to the Physics the number of teachers doing the same job (or the percentage of the number of classes given Lecture by professors and associate professors to the number of classes so done by all teachers concerned) (10 marks):

30% (or 40% of the total classes).
20-29%.
Below 20%.

III-8 The status of scientific research by the teachers and the status of cultivation of the graduate students (30 marks):

The scientific research here includes the scientific research of teaching and the compilation of textbooks or lecture notes. Hence, if the physics teachers as a whole at a college have not yet done so at all, it has to be considered unqualified for this indicator of evaluation.

1. Let the percentage of the physics teacher engaged in scientific research be K_1 (10 marks):

$$K'_1 = \frac{\text{number of teachers both teaching and researching } N_1}{\text{total number of teachers } N} \times 100\%$$

$K_1 > 30\%$
$K_1 = 10\text{-}30\%$
$K_1 = 0\text{-}10\%$

2. Let the level of scientific research by teachers during the period of teaching by L_1 (13 marks):

$$L_1 = \frac{N_1\rho_1 + N_2\rho_2 + N_3\rho_3}{\underset{\text{(total teachers)}}{N}} = \frac{N_i\rho_i}{N}$$

where N_1, N_2, N_3 respectively represent that of the state level, the ministery or province level and the college level; ρ_1, ρ_2, ρ_3, the corresponding weights. It is suggested that in the general case, $\rho_1 = 2\rho_2$, $\rho_2 = (2-3)\rho_3$, and $\rho_3 = 1$. It is also suggested that in order to encourage the teachers to be engaged in teaching research and in the compilation of teaching materials.

1) a textbook selected to be published by the Physics Committee and enjoying a nationwide influence should be equivalent to two projects of scientific researches of the state level;

2) a teaching reference book selected to be published by the Physics Committee should be

equivalent to a scientific research project either of the state level or the ministry/ province level depending on the specific conditions;

3) other textbooks or reference books can be evaluated according to the above mentioned principle:

$[_1 > 30\%$
$[_1 = 10\text{-}30\%$
$[_1 = \text{below } 10\%$

3. The level of the cultivation of the graduate students $[_2$ (7 marks):

$$[_2 = \frac{N_1 \rho'_1 + N_2 \rho'_2}{N} = \frac{N_i \rho'_i}{N}$$

(prof. and associate prof.)

where N_1, N_2; ρ'_1, ρ'_2 respectively represent the numbers of the master's graduate and the doctoral graduate and the corresponding weights (the weights are supposed to be set by experts concerned). If the graduate students are directed jointly by general College Physics teachers and professional (teaching the major physics) teachers, a conversion coefficient should be multiplied depending on the role played by them. (let $\rho'_1 = 1$).

$[_2 > 0.5$
$[_2 = 0.2\text{-}0.5$
$[_2 = \text{below } 0.2$

III-9 The number of hours of the physics lectures taught n_1 (10 marks):

$$n_1 \begin{cases} \geq & 140 \text{ hrs.} \\ = & 120\text{-}140 \text{ hrs.} \\ & \text{below } 120 \text{ hrs.} \end{cases}$$

(The above mentioned are supposed to be of non-management speciality; those of management speciality are: $n_2 = n_1 - 30$).

III-10 The condition of library reference materials (10 marks);

1. The number of per person copies m_1 calculated on the basis of the total enrolment of students: (5 marks)

$$m_1 \begin{cases} \geq 3 \\ = 2-3 \\ = 1-2 \end{cases}$$

2. The number of categories of college teaching reference materials (the popular ones) m_2 (5 marks);

$$m_2 \begin{cases} \geq 10 \\ = 5-10 \\ \text{below } 5 \end{cases}$$

III-11 Illustration experiments and electrical audio-visual aids (20 marks):

1. The status quo of the illustration laboratories (10 marks):

   Having fixed illustration rooms and responsible professional personnal, basically able to offer the items specified in the Physics Teaching Program.
   Having fixed illustration rooms and responsible professional personnal, but only able to offer 2/3 of the specified items.
   Even unable to reach the second requirement just mentioned above.

2. The status quo of the electrical audio-visual aids (10 marks):

   Having more than 10 copies of teaching films and video recordings.

   Having 5-10 copies of such.
   Having less than 5 copies of such.

Table 1 Comprehensive Evaluation

Grand Item	Detailed Items	Impressions, Scores and Comments
Evaluation of Student Cultivation	I-1 I-2	
Evaluation of Teaching Process (100 marks)	II-3 (40 marks)	1. (10 marks) 2. (20 marks) 3. (10 marks)
	II-4 (40 marks)	1. (20 marks) 2. (20 marks)
	II-5 (20 marks)	1. (20 marks)
Evaluation of Teaching Conditions (100 Marks)	III-6(20 marks)	1. (10 marks) 2. (10 marks)
	III-7(10 marks)	1. (10 marks)
	III-8(30 marks)	1. (10 marks) 2. (13 marks) 3. (7 marks)

	III-9(10 marks)	1. (10 marks)
	III-10 (10 marks)	1. (5 marks) 2. (5 marks)
	III-11 (20 marks)	1. (10 marks) 2. (10 marks)

Table 2 Lecture Quality Investigation of College Physics Theoretical Course

Department: Class (Room, Group): Date:

Grades Specific Evaluation Evaluation Factors	Excellent	Good	Medium (Qualified)	Unqualified
Scientism of Lecture				
Advancedness of Lecture				
Systematization of Lecture				
Inspiringness of Lecture				
Object Teaching Effect of Lecture				
Attention Paid to ability training of students				
Treatment of Progress, Difficult Points, Key points				

ESTABLISHMENT OF THE CRITERIA FOR THE STANDARDIZED SAMPLE EXAMINATION PAPER OF FUNDAMENTAL MECHANICS

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Abstract

The adoption of the standardization of examination is an important means to perform the educational evaluation, and the establishment of a capacious bank of examination questions is necessary. In order to set up the item bank scientfically, sample papers must be set first as the "prototype" in comparison with desired results. The so-called sample paper is a standardized examination paper set by a group of experts according to the aim of school training and the requirements of teaching plan. The work on accomplishing the item bank can run smoothly after an authoritative set of sample papers is drawn up. In this paper, an effective method of setting sample papers is offered with the procedure and the experience of sample-paper-setting for fundamental mechanics, and other respects of standardized examination are also discussed.

For dozens of years, the examination papers for the university physics courses in China have been set by the lecturers or teaching groups without an item bank. The contents of the examination can basically reflect the requirements of the teaching plan, but the contents, levels and forms of the examination papers vary in a quite wide range for different universities and different paper-setting teachers. In addition, for the same paper, the score of a student differs from that of others because of the different standards of marking. In order to evaluate the quality of physics education scientifically and to promote the reform of education, the standardized examination should be carried out gradully in the same sort of universities. To achieve this aim, the Joint Research Group of Higher Physics Education (JRGHPE) was established in Beijing in the September of 1985 by part of Chinese key teachers' universities under the guidance of the the National Education Committee. As one of its branches, the Cooperative Team of Educational Measurement and Evaluation, sponsored by Beijing Normal University, South China Teachers' University, Nanjing Normal University etc., was formed at the same time. The team starts the research with formulating a standard for the sample paper and item bank of fundamental mechanics, and with conducting the standardized examination in sponsor universities. In this paper, an effective method of setting sample paper is worked out and the relevant problems are discussed.

The standardization of examination is an important part of educational research and it plays an active role in selecting and training talented students and in carrying out the reform of higher education. What the first thing should be done in standardizing the examination of a subject is to set an item bank or a library of examination questions, but the priority is to establish the standard of sample papers as the "prototype" before completing the bank. The standard of sample papers is usually drawn up, tested, and selected by a group of experts including experienced teachers, and it must be measured with several relevant parameters such as the degree of distinction, the degree of difficulty and the degree of belief. Therefore, it is a complicated and cautious piece of work. The procedure of our work can be mainly divided into six steps:

(1) Making a two-dimensional table of knowledge versus capability (K-C Table).

The table can scientifically reflect the general requirements laid down for students in two respects: their knowledge and capability in a certain course. And the table is a basis of setting examination papers. On one hand, the making of the table should conform to the requirements of student-training, the teaching plan and the curriculum outline. On the other hand, it should meet with the consideration and the prediction of science developments as well as the need of the present society. The knowledgerow in the table should reflect both accurate and comprehensive knowledge, the capability-column should reflect different kinds of capabilities in addition to the contents given in the classes. Table I is a K-C Table for fundamental mechanics, and the knowledgerow is divided into 7 items and the capability-column and a row represents the score of an interrelated question. The total score for the whole table is 100 points under the hundred-mark system. In setting sample papers, the table can be used totally, partially or in an overlapping way to the type of measurements.

(2) Preparing questions-carids for pre-testing papers.

For setting a pre-testing paper, a number of questions must be prepared for selection. In order to cover K-C Table more uniformly, every question-card is given a 5-digit number. The figures in sequence (from right to left) represent the content of subjects, the kind of knowledge, the kind of capabilities, the type of questions, and the degree of the difficulty respectively, e.g., in Table II the number

Table I The K-C Table of Fundamental Mechanics

Score C K		1 Remembering	2 Comprehencion	3 Calculation	4 Application	5 Blazing New Trails	Total Score
1	Kinematics	1	3	2	2	2	10
2	Newton's Laws	2	4	4	3	2	15
3	Three Laws of Conservation	2	4	5	4	2	17
4	Statics	1	2	3	3	1	10
5	Dynamics of Rigid Bodies	2	5	6	4	2	19
6	Continuum Dynamics, Vibration and Wave	3	4	4	3	2	16
7	Comprehensive Questions	2	3	3	3	2	13
	Total Score	13	25	27	22	13	100

Table II Meanings of Digits in the Numbers of Question-cards

		1	2	3	4	5	6	7
I	Subject	Mechanics	Heat	Electricity	Optics	Atomic Physics		
II	Knowledge	Kinematics	Newton's Laws	3 Laws of Conservation	Statics	Dynamics of Rigid bodies	Continuum Dynamics	Comprehensive Question
III	Capability	Remembering	Comprehension	Calculation	Application	Blazing New Trails		
IV	Form	Multiple Choice	Blank Filling	Calculation	Question Answer			
V	Degree of Difficulty	Difficult	Less Difficult	Intermediate	Easier	Easy		

of a question, 12345, indicates that it is a mechanical, Newton-dynamical, new trail-blazing, calculative and easy question.

(3) Setting pre-testing papers.

Question-cards can be used to organize various kinds of paper, such as papers for tests, mid-term examinations, final examinations as well as papers for make-up examinations. Different measurements may bring forth different overlapping of the K-C Table, but at least 30 students are needed for every measurement in accordance with the statistical theory of educational measurement. We measured students of Grade 85 in Physics Department of Nanjing Normal University 5 times on different occasions with two kinds of papers: One is regular, the other is standardized. There were various forms in the regular papers, half of which were calculative and question-and-answer problems. The score was counted step by step on the basis of the procedure of solutions. But for standardized papers only forms of multiple-choice and blank-filling were used. The points were scored with "yes" or "no" according to the final results of the answer, i.e., scored with a binary code "0" or "1".

(4) Selecting pre-testing papers with the results of pre-tests.

The analyses of degrees of difficulty, belief and distinction were emphasized, and the questions of the papers were selected with item-analyzing method according to the results of the pre-tests.

The formula for calculating degree of difficulty (Pi) is

$$Pi = \frac{PH + PL}{2} \qquad (1)$$

where $P_H = X_H/X_M$, X_M is the full marks of i-th question, X_H is the average marks of high-level students (27% of the total examinees for the i-th question; $P_L = \bar{X}_L / X_M$, $\bar{X}_L$ is the average marks of lowlevel students (27% of the examinees) for the same question.

The formula for calculating the degree of belief (r_i) is

$$\gamma_i = \frac{N\sum_j (X_i Y) - \sum_j X_i \sum_j Y}{\sqrt{N\sum_j (X_i^2) - (\sum_j X_i)^2}\sqrt{N\sum_j (Y^2) - (\sum_j Y)^2}} \qquad (2)$$

where X is the marks of the j-th student for the i-th question, Y is the total marks of the same student, N is the number of the exam-taking students.

The formula for calculating the degree of distinction (D_i) is

$$D_i = P_H - P_L \qquad (3)$$

where P_H, P_L were already shown in Equation (1).

Besides, a SPE I Table (Student-problem Table) for a paper scored with a binary code should be drawn to have the item-analysis. Table III was drawn according to the result of a pre-test of fundamental mechanics. The student-line (S-line) in Table III is indicated with a broken-line, and the problem-line (P-line) in Table III is indicated with a dotted broken-line. The steeper the S-line is the less the difference of degrees of difficulties is. The intersect point Q of E-line (the diagonal) and P-line in Table III shows the average degree of difficulty of the examination paper, and the area between S-line and I-line (another diagonal line) shows the degree of distinction, the less the area is, the more the degree of distinction is. The standard of selecting questions was determined with the following parameters:

(5) Drawing up sample examination papers.

After the members of the joint research group had collected numbers of questions which could be fit to the K-C Table, the sample-paper-setting team of the experts from sponsor Uuniversities formulated a couple of papers as a "semi-finished product" for practical testing in those universities. After testing, the questions were set and selected again according to the common data resulted in a large scope under the same condition of measurements. At last, a strictly measured and authoritative examination paper was put forward as a "prototype" for item banking.

(6) Building an item bank.

The purpose of establishing the criteris for sample papers, a key to the item banking, is to set up an item bank. Our work on it is still going on. One half of the questions of the sample paper may remain as the standard to measure new questions, which can probably substitute the other half of the questions in the same sample paper if they are fit to the standard. In this way, a question-library (an item bank) will be expanded. With the consistent effort of cooperative universities for two or three years, a large, qualified item bank will be possibly built.

The establishment of the standard of sample papers has been mainly discussed. It is worth while discussing the following relevant problems furthermore: (1) Since the K-C Table is an instruction throughout the

S. No.	P. No. / No.	2	1	8	10	16	3	17	15	4	5	11	9	13	20	19	6	18	7	21	12	14	22	Ni	Ui
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	21	.95
13	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	19	.91
3	3	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1		S-line		0	1	1	19	.91
35	4	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1				1	1	1	19	.86
21	5	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	1	1	0	18	.91
23	6	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	0	0	18	.95
31	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	1	1	18	.86
19	8	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	18	.95
5	9	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	0	0	1	1	17	.86
1	10	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	0	1	0	0	1	16	.91
7	11	1	1	0	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1	0	0	16	.81
10	12	1	1	1	1	0	1	1	1	1	0	1	1	1	0	0	1	1	1	0	1	0	1	16	.81
26	13	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	0	0	0	1	0	1	0	15	.91
33	14	1	1	1	1	0	1	E-line	1	0	0	1	1	1		1	1	1	0	0	1	0	0	15	.86
34	15	1	1	1	1	1	1			1	1	1	1	I-line		0	0	1	0	0	0	1	0	15	.91
6	16	1	1	1	1	1	1	0		1	1	1			0	0	1	0	1	1	0	1	0	15	.81
11	17	1	1	1	1	1	1	1		0	1	0			0	1	1	1	1	1	1	0	0	15	.77
14	18	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	0	0	0	0	15	.91
41	19	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	0	0	0	0	0	14	.91
22	20	1	1	1	1	1	0	1	0	0	1	0	1	0	1	1	1	1	1	0	1	0	0	14	.77
32	21	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0	0	1	1	0	0	0	14	.86
17	22	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	0	0	1	0	0	0	14	.86
16	23	1	1	1	1	1	1	0	1	1	1	1	0	0	0	1	1	0	0	1	0	0	1	14	.91
40	24	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	0	0	1	0	14	.86
4	25	1	0	1	1	0	1	0	1	1	1	1	1	0	Q 1	0	0	1	0	1	1	1	0	14	.81
24	26	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	0	1	0	0	0	1	14	.86
27	27	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	0	1	0	0	0	0	0	13	.86
30	28	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	0	0	1	0	0	0	0	13	.86
25	29	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	13	.95
12	30	1	1	1	1	1	1	1	0	1	1	0	1	0	0	1	1	0	0	1	0	0	0	13	.86
28	31	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	1	0	1	0	13	.86
37	32	1	1	1	0	1	1	1	1	0	1	1	0	1	0	1	0	0	1	0	1	0	0	13	.86
38	33	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	1	1	0	0	0	0	1	12	.86
39	34	1	1	0	0	1	1	1	1	0	0	1	1	0	1	0	0	1	1	1	0	0	0	12	.81
2	35	1	1	1	1	1	0	1	1	1	0	0	1	1	1	0	0	0	0	0	1	0	1	12	.86
18	36	1	1	1	0				0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	11	.86
20	37	1	1	1	1		P-line		1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	11	.86
36	38	1	1	1	0	0	0	1	0	1	1	1	0	0	0	0	1	1	1	0	0	0	0	10	.81
29	39	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	.91
15	40	1	1	0	1	0	0	0	1	0	1	0	1	1	0	0	1	0	1	0	0	0	0	9	.77
Mi		40	39	37	36	35	34	31	30	29	27	26	26	25	25	24	21	20	20	16	13	13	13		
Pi		1.0	.98	.92	.90	.88	.85	.78	.75	.72	.68	.65	.65	.62	.60	.52	.50	.50	.40	.32	.32	.22	.32		
Si		1.0	.95	.90	.85	.75	.90	.75	.60	.65	.60	.65	.65	.55	.65	.75	.70	.70	.60	.55	.65	.70	.75		

$$D=\frac{164}{40\times 22}=0.186 \qquad I=\frac{162}{40\times 22}=0.184$$

Table III The Student-Problem Table of a Pre-test

establishment of the standard for sample papers, the statistical weight of some columns in the K-C Table should be considered in the light of the aim of school-training, teaching plan and the development of the subject. (ii) The preference of the kind of examination papers, regular papers or standardized papers, is still in dispute. The merit of the standardized examination is the unity of the criteria of paper-making. The comparison between two kinds of papers should be further discussed. (iii) How many steps the establishment of a good standard needs, what parameters the measurement of physics education needs and how the basis of formulae of measurements is provided are still problems needed to be solved.

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DISCUSS THE TEACHING IN GENERAL PHYSICAL EXPERIMENTS

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In recent years, the General Physical Experiments in every college and university in our country have been improved respectively in selecting subjects and instruments, and in requiring students. But the progress we have achieved in our General Physical Experiment, compared with the manpower and the material resources which we have emploied, is not very remarkable.

In regard to the undergraduate and graduate students I have met with, many of them display poor ability to make the General Physical Experiment. They are not able to find out connective error in simple electronic circuit and don't know how to use balance. Even the value of 2-second cycle they measured scattered between 0.8 and 2.9 seconds. They are not able to find out the cause why the results measured on the same experiment and on the same condition are obviously different. Generally speaking, firstly, the students' ability to make experiments is poor. Secondly, the ability to analyse and solve problems is poor.

On the problem of how to improve students' ability to make experiments, there are many opinions to build more Designing Experiments. According to our experience, making Designing Experiments is profitable to the improvement of students' independently working ability. We should build more Designing Experiments on Mechanics, Heat and Thermodynamics, electrodynamics, Optics. For instance, we may require students to measure the density of a small block of a certain solid and a block of wax with balance in the way which is designed by students themselves; we may require students to measure the Yang's Modulus by hanging more weights on the wire which is tightened horizontally, by which good results could be gotten. But we think it is not profitable to build too many Designing Experiments, because students in middle schools seldom make experiments. It is necessary to train students systematically with traditional methods in the first year to have them familiar with the fundamental instruments and methods and to prepare for making Designing Experiments. In addition, about error, it is necessary to build some special experiments on the measurement of error. For instance we may require students to measure the cycle of simple pendulum and draw statistic straight square chart to have them realize the law of accidental error. In the experiment of measuring the acceleration on the track of air cushion, we may require students to measure the acceleration on the track of air cushion respectively with the single light baffle and double light baffles and by choosing different original positions of the slider to have them realize the systematic error problem in the measurement of speed. While we are suggesting to build more Designing Experiments, we often hear the criticism on the Verifing Experiments. We think the Verifing Experiments are not against the Designing Experiments. Essentially speaking, the Verifing Experiments should belong to the Designing Experiments. In my opinion, the main problem of the Verifing Experiments is without reaching its goal of verifing. For instance, in the experiment of verifing the "law of conservation of momentum" by the collision of slider on the track of air cushion, the difference between momentums before and after collision could reach several even ten percent. To make the Verifing Experiment more accurately, we must consider compensating the systematic error, and if the difference between the final result of the experiment and the result of theory is within the scope of experimental measurement error, we accept the theoretical hypothesis. Therefore, the Verifing Experiments should be high standard experiments, and should be arranged to make after students recieve enough training in making experiments. Because the freshmen lack the traing in making experiments, some of the Verifing Experiments on Mechanics are hard to reach the goal. In my opinion, this kind of experiments may not be made by freshmen. If in order to accord with the pace of the theoretical lesson, we arrange some qualitative or half qualitative Verifing Experiments for freshmen.

Just now I already mentioned the order problem of experiments. Present General Physical Experiments are generally in order of Mechanics, Heat and Thermodynamics, Electrodynamics and Optics. It is mainly considered how to accord with the pace of the theoretical lessons. If it is arranged like above, it is very difficult to make some high standard Mechanical Experiments. In addition, it is not suitable to use electronic instruments. In fact, in the General Physical Experiments, a lot of subjects of experiments could be solved with middle school Physical Theory. It is not that those experiments must be arranged to make after the students have studied college physics. Therefore, in my opinion, we should change the experimental contents and order which are mainly to accord with the theoretical lessons into the new contents and order which are mainly to improve experimental training and students' ability to make experiments, then properly consider the theoretical lessons. We may divide all the experiments into three parts:

(1) Basic experiments which need elementary physical theory
Concentrate all the experiments which can be solved with the middle school physical theory.

(2) The experiments which need advanced theory
Pay attention to the co-operation between this kind of experiments and the theoretical lessons.

(3) Improving experiments
This kind of experiments may be built as the Verifing Experiment, synthetically training experiments and other advanced experiments.

Designing Experiments may be built in evry part of the experiments.

In regard to the concrete contents of the present General Physical Experiments, there are too many experiments which are about how to measure the physical constants, and there are not enough experiments which are how to research physical law. For instance, while measuring the grating constant, we should consider of observing its spectrum; while measuring the speed of sound, we should consider the affects of the temperature to the speed of sound; while measuring the ratio——e/m with the method of magnetic focusing, we should cosider the affect of the anode voltage to the measured result; while observing single slit diffration, we should compare it with the double, triple, quadruple slit diffration, etc. In addition, we should add some contents which are not discussed concretely in general text books. For instance, the relation between the motion resistance and the speed of the slider on the track of air cushion. It is profitable to add research contents in some experiments to train students' research ability.

The computer is gradually popularized in our country. The problem of how to apply computers in General Physical Experiments should be discussed. Since 1984, we have disposed 30 pocket computers for the General Physical Experiment and teachers for the experiment teach the freshmen "BASIC" computer language. Ordinary freshmen are able to program for processing experimental data. We think the application of computer in experiments should promote the improvement of experiments. In our experiment on the statistic distribution of error, because we processed the experimental data, we quickened the pace of making the experiment, so that we added some more contents about statistic experiment. We think it is insufficient for computers only to process data, we should apply computers to the automatically controling experiments and to collecting data. Of cause the contents of experiments should be improved and amended with the increase of applying computers.

The basic aim of experimental teaching is to improve the students' ability to make experiments. In order to raise the efficiency of teaching in experiments, besides the teachers' enthusiasm, there must be students' enthusiasm. Therefore taking every step of the experimental reform, we should think about how to stimulate the students' interests and enthusiasm.

With my imperfect opinion, I wish to consult with every expert and professor.

A TENTATIVE STUDY OF THE UNITY BETWEEN TEACHING BY EXPERIMENTS AND CULTIVATING ABILITIES IN PHYSICS COURSE

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P.R.C.

We are in an era of new technical revolution, an era full of knowledge which is ever increasing with books. It would be by no means possible for a student to cover all knowledge within a limited span of time, neither would it possible for a teacher to pour to students all he knows within limited teaching hours. As everybody knows, there is a limitation of the capacity of knowledge accumulated in a man's brain. Take a pocket for instance. Large as it is, it cannot contain everything. To bring it into full play, it would be better to use it for placing keys to various kinds of wardrobes. With keys one will have everything. Therefore it's ever more important for a student to learn how to open the treasury of knowledge than to learn from books. As for a teacher, he should deliever to students not only the keys, but also 'fitters handicraft' of making the keys. Once a student masters this handicraft he will be quite at home in opening any treasury of knowledge to acquire what he needs. This principle is applicable to the teaching of theory and experiments at that.

In other words, the society demands that we should teach not only knowledge in the classroom, but, more important, the way to acquire it, to search after it, to think logically and multiply, and we should, by all means, cultivate students' abilities to study independently, abilities to sense information, to think, to imagine and to solve practical problems, so as to not only lessen brain's burdens, enforce brain's function to memorize, but to bring into full play brain's function to sense, to judge and to imagine.

Teaching is the main way to cultivate students' abilities in every respect. But teaching is not merely an art, it concerns with a series of theoretical problems. We will find no basis to rely on in our teaching unless we have a clear idea of these theoretical problems. In my opinion, the following three problems are to be solved as regards the present teaching work.

First, the system and the guiding principle of teaching. The system which takes classrooms, textbooks and teachers as the centres ('three centres') is a traditional close-type teaching. It results from the guiding principle of one-way teaching and cannot meet the requirment of cultivating the abilities of creation and the abilities of dealing with changes. With the development of modern science and technology, more permeation and overlap of subjects and more frontier sciences have come into being. There is a tendency of a complex of subjects. Students should break through the close-type teaching system, to get what they lack from wherever they can. It is thus foremost necessary to change the close-type into an open-type system, to establish a new guiding principle of teaching for exploring intellegence and to adhere to the unity between teaching knowledge and developing intellegence, so as to let the students be always positive in their study.

Secondly, two relations in the teaching process. The teaching process is an active process in which teachers and students exchange information, share opinions, develop abilities, cultivate emotion and willpower. It is a complicated process. If this process is regarded as a network, teachers, students and teaching contents are the three main factors constructing the network. If these three factors are properly connected, closely related, the whole network will fully function and the teaching process is effective. It is therefore necessary to bring into light the two relations — the relation between teachers and students, and that between teaching and learning. I think that in the teaching process students are the actors while teachers are the guide. Students begin to know Nature in the process, while teachers guide and help students. As a Chinese saying goes: 'With the help of teachers you begin, by your own effort you advance.' This saying pinpoints the relation between teachers and students. It takes teaching process as the guide for learning and learning process as the base for teaching. With this principle set, the actors i.e. students, will get rid of the bondage of the 'three centres', turn from the passive into the active. With proper connection, close relation, integrated emotion, shared information and good cooperation, teachers and students will, like conductor and players in an orchestra, perform pieces of sweet music.

Thirdly, teachers function as a guide. Teachers' guide should not be overemphasized, otherwise there will be a comeback of 'three centres' teaching. Teachers' function as a guide, I think, should be exercised in the following respects:

1) To select teaching materials of basic theory, basic knowledge and basic skill training, taking into account what students have already learned; to work out measures for putting emphasis on the basic teaching.

2) To carefully lay out teaching procedures according to the rules for study; to adopt suitable methods and various ways in teaching.

3) To apply different teaching methods according to different logical thinking and practical abilities of students, and to give them guidance respectively, so as to cultivate and develop their respective abilities.

4) To put emphasis on the cultivation of special abilities in accordance with special aims of different schools and specialities; especially to put in the first place the normal aims of normal universities and colleges.

5) To educate students throughout the whole teaching process with professional morality in line specialities and pedagogy; to educate students while teaching book knowledge by setting a good example for them with teachers' good conduct.

The above-mentioned are our points of view. In the practice of teaching reform in the past few years, we have come to realizé that the following aspects are applicable in teaching physics by experiments today.

I. Careful Selection of Teaching Materials

Materials for teaching by experiments should meet the demand of cultivating different talents of specialities and should take into consideration the present conditions of the middle schools. There is a shortage of instruments for doing experiments in the middle schools and the teaching by experiments, the training of practical abilities, even the teaching system itself are inferior. Anyway middle school students lack proficiency training. So the freshmen in the university should start from scratch and begin with how to take measure of length, time and mass of things. The second-year students begin with basis circuit. As for optics experiments, they are seldom done in the middle schools. Thus, in selecting the items of experiments for the first and second year students, we take for main reference the 'Syllabus of Teaching Physics by Experiments' issued by Education Ministry and have compiled by ouselves a set of materials for teaching by experiments which are suited for emphasizing the learning of basic theory, basic knowledge and the training of basic proficiency. This set of teaching materials only serves as:

(1) Introduction to the function and the structure of the apparatus in the laboratory.

(2) Introduction to the principles and conditions for doing experiments.

(3) Caution and questions to think over.

(4) Additional items of experiments.

The procedures of doing experiments are not included. They are left for students in their preview before class, for the purpose of promoting students abilities to study independently and initiative.

II. Ways to Conduct Teaching

Physics by experiments is a basic course of technique, a good way to cultivate students' abilities of independent work. Various ways to conduct teaching will ensure the fulfilment of this purpose. For several years, we have adopted the following ways in our teaching:

1. Doing experiments in groups by turns.

To make full use of the sets of apparatus so that every student is sure to have a set of it for independent operation, we divide the items of experiments into two parts — the compulsory and the alternative. The former one is for basic training. It includes learning the basic theory of experiments (error theory) and the basic knowledge and learning to use basic measuring apparatus. The latter one is for advanced training. It includes how to take measures of the same and different physical magnitude by various means, how to fit and regulate the apparatus and how to do complicated experiments. The compulsory and alternative items are open at the same time to students by two or three turns.

2. Opening test

In order to step up basic training, to put students in an active active state so as to cultivate their own abilities, we take the following measures so that students have more chances to work in the laboratories.

(1) We break the old rule that each student is to accomplish one experiment every week and establish a new one that each student is to accomplish only a certain items of experiments including both compulsory and alternative. The total numbers of the items are 60% of the numbers of the weeks for doing experiments in a semester. For instance, there are 18 weeks for doing experiments in a semester, according to the old rule each student should accomplish 18 items of experiments, but now 12 items are enough. More time is left for repeating the training of designing experiments, deep-going research and advanced study by students themselves.

(2) Opening laboratories libraries and reference rooms are places students frequent in their study of theory. For doing experiments the only place they go to is laboratories. For their convenience, we decide to open the laboratories twice a week at a fixed time and at any time according to students' need.

3. Designing Experiments

Designing experiments is a process in which students test their independent abilities and comprehensive techniques by themselves after having learned the methods and skills of operation in the whole semester. In this process are demonstrated students' independent abilities no matter strong or weak, and that does good to teaching students accordingly. The topics for designing experiments may be either chosen by students or suggested by teachers. With apparatus or materials supplied by the laboratories, students work out plans for experiments, fit and make the sets of apparatus. This way to conduct teaching completely breaks the 'three-centres' bondage and provides quite a favourable condition for bringing students talents into full play.

Take a student of 1983 Class as as example, the topic he selected is Measuring High Resistance by Means of Leakage. In his first measurement the error rate was 4[illegible]%. Through careful analysis he found the rootcause and improved his measurement. The error rate dropped to 2%.

Another student's topic is A Test of $M=\sqrt{L_1L_1}$, Mutual Inductance of Two Coils at leakage Flux-free.

In his first test by means of Maxwell bridge the error rate reached 94%, compared with the value of the theory. Through repeated experiments and analyses, he found it was due to the great leakage flux caused by using the wrong size of the coils. He made another pair of coils and the error rate dropped to 6%. Although in designing experiments there are few experiments of creation, yet students learn to apply theory into practice through choosing topics, looking up in resource materials, working out plans and designing experiments and, what's more, they learn a lot of craftsmanship and the knowledge they cannot acquire in the books. No doubt, this way of teaching is of great effect for cultivating students' abilities. It does good to students of physics departments of teachers universities and colleges to reset apparatus and make necessary fittings.

4. Holding Seminars

This is another way of teaching. We held our first seminar in the second semester of 1984 Class. Exactly speaking, a seminar is a chance through which students compare notes after a period of experiments, air their opinions on the search of some laws governing experiments, such as how to analyze the errors in an experiment, how to do a successful experiment, how to improve some methods in the experiments, etc. From seminars teachers get much feed-back information and learn a lot from the response of students and know better about how the students study the experiment course. As for students, they acquire others' strong points and overcome their own weaknesses. They become more conscious of and interested in their study. Teachers and students learn from each other, promote mutual understanding and set up public information treasury.

The time, content and way of seminars are announced at the beginning of the semester so that students can deliberately design their plans for doing the experiments and make a carefull and thorough study of the contents, methods and rules of the experiments in the whole process. Students' logical mind is busy and there is no doubt about good result in both teaching and learning.

The organizer and sponsors of the seminars are monitors or other student cadres. Teachers act as advisers and judgers. Marks are given right away.

In this way, students can learn not only how to write an essay with scientific and logical order, but how to express themselves orally, how to state strict physical concepts and the process of experiments and how to get rid of stage fright, as is particularly required for students of teachers universities and colleges. In my opinion, it is better to begin this way of teaching from the second semester of the first school year.

III. Ways to Teach Knolwdge

As I have mentioned, in the teaching process students are the actors. They are subjective body, while the objective body is the contents of experiments or rather apparatus for experiments, which are the direct source students acquire knowledge from and develop abilities with. In this sense, contents of experiments are superior to those of theory teaching. So in teaching physics by experiments, teachers should begin with apparatus for experiments. For it is also in conformity with the law of recognition in the process of study, which can be formulated as:

Sensible recognition ——→ rational recognition ——→ practice

Considering the characteristics of physics experiments, the process of study might follow another formula:

Known rational recognition ⟶ sensible recognition ⟶ new rational recognition ⟶ practice

The 'known rational recognition' means the theory knowledge students have learned in their theory course. From 'know rational recognition' to 'sensible recognition' is a process to transfer theory formula into fitting apparatus for experiments. So apparatus for experiments is the starting point in the teaching.

As we know, the apparatus for physics experiments is a set of fittings designed on a certain condition according to a certain law governing the motion of matter. And we can test the law by making use of this set of fittings too. For instance, we can take measure of the value of local acceleration of gravity by making use of both single pendulum or free falling body. These two sets of fittings are made according to certain laws governing different motion of objects. The formula for the period of single pendulum is $T = 2\pi\sqrt{\frac{l}{g}}$, while the formula for the motion of free falling body is $H = \frac{1}{2}gt^2$. These two formulas belong to the theory knowledge students learned long ago. They are known rational recognition, which is by no means necessary to be taught again. What is necessary is to begin with apparatus.

From 'sensible recognition' to 'new rational recognition' is a process to understand the principle, condition and method by which experiments are done for taking measure of physical magnitude with the help of the apparatus. This process is the main point in teaching knowledge. From 'new rational recognition' to 'practice' is a process for students to operate experiments after understanding the principle, condition and method. In this process students learn how to observe and analyze physical phenomenon, how to regulate apparatus, how to collect data and how to analyze the result. This process is the main point for teachers' instruction and the key point for cultivating students' independent abilities, for delivering to students 'fitters handicraft' of making the keys.

In this regard, we adopt the following ways in teaching by experiments:

1. Self-taught preview

The preparation before experiments is called preview. It covers:

(1) To understand the main points, difficult points, demands and questions put forward by teachers before doing experiments.

(2) To be familiar with the principles of experiments stated in the guide for experiments and to peruse the guide and other reference books to find answers to the questions.

(3) To have a look of the apparatus to be used in the laboratory and to read the specification.

(4) To work out the procedures for the operation and the forms for the data in the experiments.

We put emphasis on self-taught preview, because it is the start for cultivating students abilities to read and to make a deep-going study of the texts. Our purpose is to gradually establish students' self-taught habit ever since the first school year. While putting emphasis on self-taught preview we give students some necessary guidance. The main instruction should be given on the function, the characteristics and the how-to-use of the apparatus. The process in which students work out the procedures for experiments after understanding the contents of the experiments through self-taught preview is a process in which students develop their abilities to sum up and to exert brain's function to sense and to imagine.

Students are required to read the specification of the apparatus by themselves so that they can not only acquire sensible recognition of the function, structure and use of all parts of the apparatus, but also establish their good habits of not putting apparatus operation until after understanding its function.

2. Heuristic answer

Before doing experiments students are allowed to raise any questions. And then teachers answer the questions just raised or those not yet settled. To enlighten students' thinking, teachers adopt heuristic methods in answering the questions except for those which should be explained clearly. Sometimes teachers raise questions and let students find the answers through the operation.

In this way teachers arouse students' hunger for knowledge and make students realize that only by practice can they acquire truth.

3. Instruction to the point

Students are usually in a bustle with tension when they just begin with the experiments. Teachers should look into students' mental state, be aware of what problems to come up, and give instruction to the point. So far as I know, students are usually impatient for a success, neglecting to observe, analyze and judge the phenomena. They are anxious to take measure before conditions are ready, or go in blind without knowing the function of every part of the apparatus or the right way to do the experiments and so on. All these lead to failure and the experiments get nowhere.

In order to bring the experiments into due effect, we divide our instruction into three periods, each with its own aim and emphasis.

The first period — the beginning period. In this period teachers pay attention to what students do at the first step, whether it is right or not. If it is wrong and will bring harm to the apparatus, teachers must immediately stop it and ask students to check up. Students are not permitted to start again until they find the mistake. Teachers need not stop students if their mistake will not bring any harm to the apparatus. Let students find it in their own operation.

The second period — the stable period. In this period the apparatus is ready, everything is in order and students begin to regulate the apparatus. Teachers must go over the operation process in each student group, find typical example of irregular operation if there is and call students togather to make comments on it and then break them into groups again. In this way teachers give instruction to the point which is difficult for students to tackle. And students get better understanding of the principles of the operation. Instruction this way is best welcome.

The third period — the guard-pass period. In this period students begin to take measure of the data. Teachers go from group to group to check up the data, giving timely instructions or talking with individual students on how to make analysis and judgement. Teachers should be more patient and strict toward poor students, paying careful attention to what they might think or asking them questions from time to time so as to give whatever help they need. Teachers should guard the pass for every student without exception. No one will get pass until he is through with the compulsory item.

4. Ability to fix

It is likely to have some troubles with the apparatus in the experiments. Students are allowed to repair the apparatus under teachers' guidance. Though there may be a little delay in the experiments, students learn something practical. They gain more besides what they acquire from books.

In a word, to combine teaching with cultivating abilities, teachers must work with all their hearts, stick to their own post as a guide. They should be keen observers, should not let anything escape their eyes, and, above all, should see that what students do in the laboratory is well arranged.

DEVELOPING THE RESEARCH WORK ON LAB TEACHING RAISING THE TEACHING LEVEL

Mao Shuqi (Lanzhou University)

Our laboratory was founded in 1980. There are 11 teachers and 9 technicians in our laboratory. Now about 50 experiment subjects are available. Every year about 200 graduates and students come into our laboratory.

Since the last few years we have tried to raise the teaching level by developing the research work on lab teaching. It is shown that our efforts are fruitful.

The subjects of research work on lab teaching cover a wide area. These years our reseach work on teaching mainly concentrated on the following four aspects: namely, on the arrangement of course in morden physics experiments, on the teaching method, on the design of teaching lab instruments, on the improvement of the experiment details.

The course in morden physics experiments is one of the compulsory courses in our school curriculum. It is a course for the senior university students in physics and other closely related specialities. In the past, students do each subject by taking the same time. Now we have altered it so that a student may have the chance to learn certain numbers of subjects in different fields and he has also the chance to major in one or two subjects, such as x-ray diffraction analysis, electron microscopy, low temperature technique and applications, laser raman spectroscopy ...... In these subjects the foundamental theory and the frontier in that field are recommended and more opportunities are offered to the students to do more lab practices so that they may know more about that field and obtain more training of research work.

On the teaching method, we emphasize that it runs through the whole teaching process to enhance the student's abilities to work on their own. We have set up a regulation of preview. The students were told to read the reference material and try to make clear the experiment priciple, instrumentation, operation... on their own before going into the lab. At the beginning of the class there will be an extensive discussion between the students and the teacher on all the respects. The students will be asked to answer a series of questions. In this way the teacher may check how well the student know and enhance their abilities to analyse problems. During the experiment we set demands on students to complete the experiments themselves, to observe the phenomena and try to explain them. We set demands on students to record the measurement data strictly according to the facts. The students are requested to manipulate the data seriously. At the end of the class there will also be a discussion between the students and the teacher on the error analysis and to show the way of further improvement.

We have designed some instruments and devices for lab teaching to satisfy the needs of teaching. We have designed a set of furnace with variable temperature from room temperature to 350°C, the temperature can be stabilized at a given value. It is an accessory for the x-ray diffractometer. It does not cost much but it is useful. It may be used to the research on phase transitions in some alloys (In-Cd alloy, for example) and crystallization in some amorphous material, now it is available as an experiment for the students. We have designed a model L AD-DA converter. It is a set of lab teaching instruments. The building blocks mode is adopted so it makes the physics principle easy to be understood. We also set up a set of laser raman spectrometer by combining a model HRD-1 doublemonochrometer, a photon-couter and an Argon ion laser. During the teaching practice it is found that the photomultiplier tube lacks protective device and the wavelength display is not convenient, so a microcomputer controller has been combined with spectrometer. Now the PMT is in safety, the students may operate the spectrometer in the way as in an ordinary laser raman spectrometer, the students may concentrate their minds on thinking of physics ideas during the experiment instead of worrying about the wavelength positions.

In the lab teaching practice it is found that some of the teaching methods may be improved, some of the lab teaching details may be deepened, the weakest link in teaching may be strengthed, all these are the subjects of teaching resaerch. In the experiment on spectrum of soldium atom, it is found that the spectral terms can be determined by means of a computer instead of consulting a Rydberg table. In the topic 'The principle and the applications of microprocessor', we improved the software design, 14 functions are added to the LTP801-A BUG under the conditions not to occupy the user's space $PRON_1$ and $PROM_2$, and not to change its hardware. We also compiled someteaching reference materials to direct the students to learn the drawing of an experiment curve and the manipulating of data exactly. All these efforts are fruitful.

We may conclude that based on the practice in recent years the resaerch work on lab teaching is an important way to raise the teaching level. Its achievements serve the teaching directly. It belongs to the resaerches in new knowledge, it may enrich the human knowledge treasure-house.

During the teaching research practice, the teacher can raise the teaching level and heighten his academic level. As the technicians may take an active part in the practice, their standard can be raised effectively.

The teaching research work is worth our while. We will continue to develop the research work in this field.

AN ATTEMPT ON STUDENT'S EXPERIMENT--------MAKING OF THIN FILM BY VACUUM EVPORATION AND MEASURING THICKNESS OF THE FILM.

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In spite of the rapid progress in scientific technique of today,physical experiments for the general education in Japanese universities still remain traditional and conventional for the use of old fasioned equipments and simple tools. I suspect such a situation might be same,more or less,all over the world, even in the United States and other advanced countries in Europe.

Twenty years ago,the conventional style physical experiments using simple equipments and tools were practiced in our Aichi Institute of Technology. Of cource, such experiments have their own merits to make students learn an experimental planning and how to deal with the experimental data. These experiments, however, may be not so attractive for the students, because the tools they use are so simple and antiquated that they are not interested in the experiments itself.

in order to improve such a situation,we developed some themes for student's physical experiment in which students could make use of several new kinds of instruments employed widely in the basis of new scientific technology. We were very happy to see that the students showed great interest in their experiments by using these new types of instruments. We also found distinctly the rise of learning will of the students for physical experiments. I introduce you one experimental theme out of our developed themes.--Making of a thin film by vacuum evaporation and measuring thickness of the film.

Thin film by vacuum evaporation is used in many branchs of optics and electronic industries. (for example, ① antireflection film, ② optical mirror, ③ optical filter,④ surface coating of plastic,glass and metal for hardening surface or decoration,⑤ connecting element,⑥ thin film transistor, ⑦ integrated circuit,⑧ thin film memory,⑨ photo-electric element,etc.)

In order to show the most popular vacuum pumping sistems,we designed a vacuum-evaporator using oil diffusion pump and oil-sealed rotary pump.

Standard system of vacuum evaporator in the market has a large vacuum tank (400 mm ϕ), therefore we need a large vacuum pump system for it. But such a big pump is not necessary for our experiments, because the specimen we use is very small and we must reach to high vacuum state in the limited time,and also we hope to cool down the diffusion pump in a short time after uses.

The capacity of bell jar tank is less than a tenth to standard set's.

The cylindrical vacuum tank is made by stainless steel for safety. It's external size is 165 mm in diameter and 230 mm in height. Vacuum pumping system is constructed by 2-inches oil diffusion pump and fixed vane oil sealed rotary pump(Cenco type). Pumping speed of diffusion pump is 160 l/sec,and pumping speed of oil sealed rotary pump is 50 l/min . This pumping system has the least pumping power in the market,but this system has sufficient power for our small vacuum tank. The air pressure in tank reaches to sufficient vacuum states for evaporation at 20 ~ 40 minutes.

We direct students to evaporate under the vacuum state of 3×10^{-5} Torr.

Production of the specimen and measuring thickness of the thin film

We utilize the glass base of used spectrographic photo plate in order to obtain the base plate of good flatness. Spectrographic photo plates have been used in another student's experiment. We boil the photo plates for hours in a big pot and peel off gelatin from glass plates. The glass plates are washed with distilled watter and organic solvent. The specimen must have a high reflectivity in order to obtain maximum quality fringe line (sharp, dark,and narrow)in multiple beam interferometer. We coat a glass plate with vacuum-deposited layer of aluminium.

The student's handling metal must be low boiling point and must be no harm for the health. It needs to distinguish cleary between aluminium and another metal films in colors. We choosed antimony at first for easy treatment, but we should give up using antimony for slightly harmful quality. Bismuth is selected as the evaporating metal now. An appropriate piece of bismuth(about 30 mgr.)is distributed to a experimenter. A student measures accurate weight of bismuth by automatic electronic balance. We can estimate the thickness of deposited metal layer from the shape of tungsten filament board, distance between filament and specimen, and the mass and the density of evaporated metal.

$t = (m \cdot \cos\theta) / (\Omega \cdot r^2 \cdot \rho)$

t : thickness of deposited metal layer

Ω : solid angle at which the metal is evaporated from filament board

r : distance between filament and specimen

ρ : dencity of metal

m : mass of metal

θ : tilt angle of the specimen

The dencity of deposited metal layer differs from that of bulk metal, but we can estimate roughly the thickness of evaporated metal layer by this formula.

We explain to students the structure of vacuum pumps and valve systems, and instruct the treatment of this vacuum system, and then demonstrate by using un apparatus. Geissler discharge in low degree of vacuum is the important demonstration. The change of Geissler discharge in low pressure show rough standard of states($\sim 10^{-2}$ Torr).

The vaper of organic solvent shows the characteristic discharge colour. This phenomenon is used to seek the portion of leak.

When the degree of vacuum in bell jar tank reachs to sufficient state ($\sim 3 \times 10^{-5}$ Torr), evaporating current to the filament board is transmitted under the director's guidance. The piece of bismuth is sent flying by too rapid heating. Then the whole quantity of bismuth can not be evaporated.

On the other hand too slow heating of filament board burns rubber packings that keep vacuum isolation between electrode and insulator. Bismuth layer is vacuum-depositted on a part of aluminium base plate.

Vertical surface variation, departure from perfect smoothness on the surface of the specimen, is measured by multiple beam interferometer.

The Fizeau plate(half-mirror with high reflectivity)contacts with the specimen and is tilted at a slight angle to form an air wedge.

The interference fringe pattern produced in the air wedge is transmitted through the Fizeau plate to a filar eyepiece. The pattern is measured with the eyepiece hairline, whose movement is indicated in arbitrary units on a graduated knob. The interference fringes produced in the air wedge are parallel lines that describe equal thickness contours. The fringe line spacing a is equivalent to one-half wavelength(273 nm). The height of the specimen's surface variation is determined by the ratio of the fringe line offset(b) and spacing(a).

$a \tan\theta = \lambda / 2$

$b \tan\theta = h$

$\therefore \quad h = (b / a) \cdot (\lambda / 2)$

a : fringe line spacing

b : fringe line offset

θ : tilt angle between Fizeau plate and the specimen

h : height of the surface variation

From this experiment,students are expected to study the subjects as follows

1) The structure of vacuum pumping systems

2) Vacuum discharge in low degree of vacuum

3) Delicate measurement by optical interferometer.

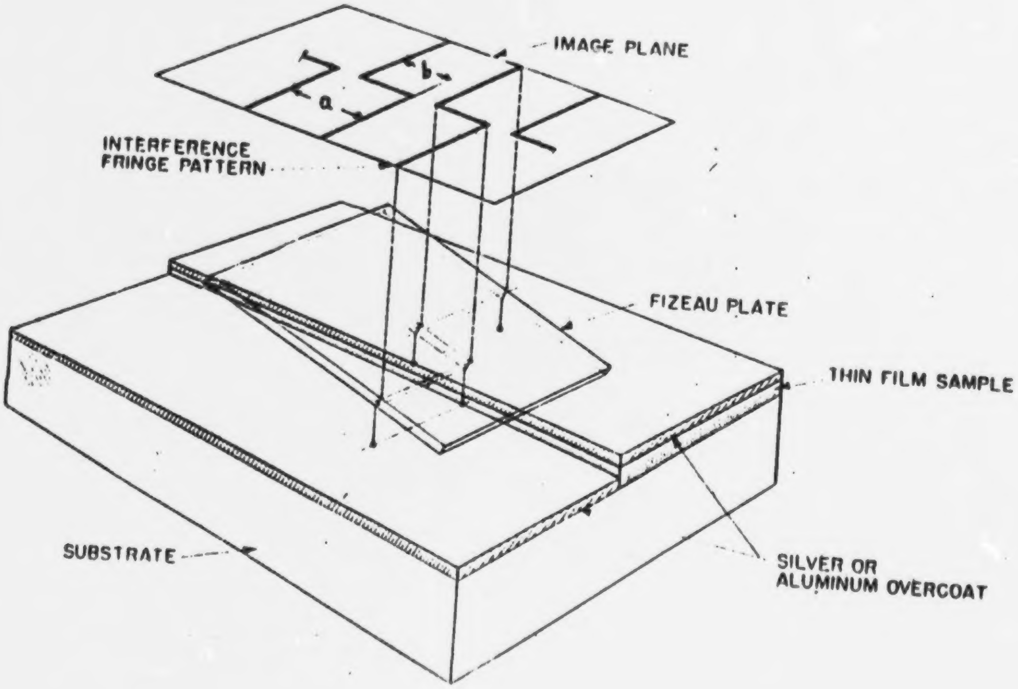
IMAGE PLANE
b
a
INTERFERENCE FRINGE PATTERN
FIZEAU PLATE
THIN FILM SAMPLE
SUBSTRATE
SILVER OR ALUMINUM OVERCOAT

The Application of TV Video in Physics Teaching

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Abstract

In this paper, we will first describe the application of TV video in basic physics teaching in our department, and discuss the function of TV video in teaching with numerous examples. Compared with classroom demonstration experiments, TV video film can provide a clear and vivid presentation of the experimental phenomenom to all of the students, surmount the limitations of space and time encountered in on-the-spot demonstrations by various techniques. It can present a successful experiment in one action and obtain the best effect. It may be used to verify various theorems and laws qualitatively or quantitatively. Several experiments may be collected in one film to explain one topic and strengthen the understanding of students. It can also increase the knowledge of the students, widen their vision, and promote their interest to study.

Second we will discuss the various ways to use the TV video film. We can explain while broadcasting, broadcast first and explain second, or vice versa, it can also be used in stage summarizing, can be used in combination with demonstration experiments. It can be used in the presentation of the principles, structures and operation of various apparatus.

Finally we discuss the essentials in making a good teaching film. It includes the proper choice of the topic, extensive collection of the related materials, the enrichment of the content of the film, elaborate design and efficient use of TV film techniques and the close coordina-

tion between the teachers and the technical personnels involved.

General physics is a subject of broad scope, generally includes Mechanics, Electromagnetism, Heat, Optics etc. It is a preliminary and basic course for further study in physics and other branches of natural sciences. It has a strong experimental flavor and has close relations with many phenomena obsersed in dayly life, in production and in nature. So in teaching this subject, we should try to enable the students to learn the abstract concept on the basis of perceptual knowledge, to have a vivid and correct physical picture as well as to know the word expressions and mathematical formulae of the physical laws they learn. Based on this idea, we have designed, produced and bought many apperatus for demonstration experiments, and made great effort to improve the quality of these experiments. These efforts have been of great help to our teaching. However, because of the limitations of space and time, we have difficulties in some of the experiments. In some experiments the quality have not been satisfactory, and in some cases we have failed to produce any apparatus to demonstrate the physical phenomenom.

With the development of electrically and audiovisually aided education, slides, projectors, recorders, videocorders and other instruments have be come indespensible tools in the teaching of many branches.

In recent years, we have improved and perfected our video equipments. Now we have seven monitors and four players. Four monitors connected with players are fixed in a big classroom which can accommodate 180 students. In this classroom, a teacher may operate the equipment himself, and so broadcast a film during his lecture. Some monitors and players can also be brought to a small classroom with a wheeltable. In the preparation of a lecture, a teacher may analyse, study and copy a film in the preparation room. At the same time, we continually increase the skills of the experimental technical personnels, attract many teachers and senior students to take part in this work. Many of them now has the ability to deit, direct, record, and show a video film. Up to now we have made more than 20 films, and copied more than 20 ones. With these facilities we can use video films actively and suitably, and solve many of the difficult problems in teaching.

Now we will discuss three aspects of the problems in detail.

I. The function of video film in fundermental physics teaching

A). TV video can provide a clear and vivid view of the experimental phenomenom to all of the students, and thereby improve the effects of the demonstration experiment.

In some experiments, the phenomenom is clear and stable, and when seen clearly, the experiments can give a vivid demonstration of the phenomenom and the physical principles involved. However, in a classroom with many students present (generally more than 100), only the few students near the experimental apparatus can see clearly the phenomenom of the experiment which the teacher performed in class, this will greatly affect the result of the demonsetration. With the TV video, the view can be enlarged, and sometimes several monitors may be used simultaneously, every student can see the phenomenom clearly.

For instance. A small glass tube (ϕ3cm) was used to demonstrate the "layer flow" and "turbulent flow" in a classroom in the past. Most students were unable to see the "flow line" in the tube. But after using the TV video in this experiment, the thin blue "flow line" become very stbale and clear. As the speed increases, the flow changes from "layer flow" to "turbulent flow". Student can clearly see that during this process the flow line gradually becomes chaotic. This demonstration gives the student a vivid physical picture of the abstract concept "flow line".

Another example is the demonstration of "Lorentz force". In the original form of the demonstration, most students can not see clearly the trajectory of the electron beam. So the demonstration cannot demonstrate the low of electron motion in a magnetic field effectively. After the TV video is used, the trajectory of the electron beam is clearly shown. Students can see the deflection of the electron beam, the dependence of the radius R of the round orbit on the velocity $\vec{V}$ of the electron and the magnetic field $\vec{B}$ when $\vec{V}$ is perpendicular to $\vec{B}$ and the spiral trajectory when $\vec{V}$ is not perpendicular to $\vec{B}$. This demonstration deepen the understanding of the students of this law.

The demonstration of Fresnel wave belt is another example. It is difficult to demonstrate this phenomenom in a big classroom. But with the video, the students can clearly see that the "Fresnel wave belt" can form real and vitaul images, and that it is a component with several focus and large chromatic abberation.

B). Using special techniques in TV video, we can overcome the difficulties arisen from the limitation of space and time. For instance, A small object can be enlarged, or vice versa. A moving picture can be paused. A fast process can be slowed down. The slow process can be fastened. It can also show the experiment from different angles and different sides. It can be inserted, compounded, compared. There can also be close up or moving pictures. Weak sound can also be magnified. These special techniques make the phenomenom we want to show more apparent and more vivid.

Brownian motion of particles can not be seen by naked eye. In the past, students observed the phenomenom through a miscroscope. It took much time for 100 students to see the phenomenom and if a student happened to contact the table, the Brownian panticles will be lost from the eyefield, and the microscope must be readjusted. Now in a film taken with a misroscope, particles are constantly wriggling. Their movements are more convincing than the picture of zigzag lines in a textbook. We also use moving pictures to explain vividly how Brownian particles move irregularly when collided by other particles.

The next example of the special effect show we will take is the teaching film demonstration the vibration of individual particles in a standing wave. There are both nodes and loops. A standing wave and a travelling wave could be put in a same view for comparison. Slow motion could be used to show the opposite phases of particles at the two sides of a wave node. This deepen the understanding of the students to the characteristics of a standing wave.

Generally students find it difficult to follow the induction and imagine the description of the teacher about the interference and diffraction pattern and their changing process in optics. Besides a demonstration is rarely clear. But using the video, we can gradually magnify the interference and diffraction pattern, and show the beautiful strips to students with special effect shot. For example, in demonstrating the Fresnel round hole diffraction, students can see not only the motionless strips, but also the real process of exchange of bright and dim in the pattern center when the position of light source or the observing screen is changed. Students can see the emergence of strips or the contration of strips towards the center when one of the reflectors of a Michelson interferometer is gradually moved. All these videos are warmly welcomed by the students.

In the past, we used two forks to demonstrate the phenomenom of "beat" in class, the beat sound is rarely clearly heared. Now in the teaching film, the picture and the sound are both recorded in the photographic room with good equipments and good environment. The sound effect of the film is also very good, ever the changing of the "beat frequency" can be heared.

C). Demonstration with video can succeed in one action and get the best result. Some experimental phenomenom may only appear under strict experimental condition, and will disappear quickly. Although a teacher may repeat the experiment repeatedly in his preparation, he is still not certain to succeed in one action. But repetition will affect the spirit of the students and reduce the effect of the demonstration. Moreover, repetition may result in the violation to the plan. For an example take the demonstration of critical phenomenom. In the phase transition theory the critical state is very important. When students lack the perceptual knowledge of critical state, it is difficult for the teacher to describe the critical phenomenom, and students find these phenomenom difficult to imagine. So demonstration experiment is an indespensible crux. But usually the teacher can not succeed in one action, and even succeeded, the critical state will disappear quickly, the critical milky light might not be observed. But when video is used, we may take down the view of several repeated experiments. Choose one with best effect copy it, and add the sound. In class the experiment may be shown repeatedly and get the idea effect.

Another example is the "sun redden" experiment demonstrating the light scattering phenomenom. It takes much time to do it in a class, and is difficult to get good effect, ideal effect may be taken down in a video film.

D). Verify the theorems and laws qualitatively or quantitatively.

For example, the theorem about the motion of mass center is a fundermental law in mechanics, but student feel strange, abstract, even suspicious when they first hear it. This difficult problem can be solved using a video film. We put a small boat with a magnet in a cup of water. Thecup is put in the maghetic field of a Helmholtz coil, when electric current is switched on, we may see that the mass centet of the boat is still, but the boat is rotatng about the center, this is because the vector sum of the external force is zero, but the resultant momenta of external force is not zero. We have also made a series of quantitative experiments on a air-table. The position and movement of the mass center are depicted on a graph. Then after a series of measurements and computation, we verified this theorem quantitatively. The little ten-minitus film deepen the understanding of students to the theorem.

E). In a TV video film we can surmaount the limits of space and time, collect several experiments together to explain one problem and deepen the understanding of students. For example, in the film "angular momentum conservation" we collected an expract of the motion of a top in the "sky-lab", an extract of the rotation of the main propeller and tail propeller of a helicopter, some close-up shots of the rotation of some skating, diving and gymnatics sportsman. All these strengthen the comprehension of students to the principle.

F). Video film can increase the students' knowledge, widen their vision, and intensify their interest of study. In the preparation of a film, we pay attention to the various teaching principles. Besides, we also pay attention to the aesthetic aspect of the film. We choose bright colours, beautiful music, precise, concise, lively and vivid explanltions. We inserted some outside scenes, some general knowledge related to the topic, and the application of the physical laws in production and scientific study. These treatments strengthen the effect of the film, increase the knowledge of the students, broaden their vision, and intensify their interest of study.

II. Some wyas to use video in teaching

A). Explaining while broadcasting. Lecture and film may be given in turn. This closely combines the video with lecture. Usually it can save time, and has good effect. This is the most frequently used way in our teaching.

B). Broadcasting first and analysing and summarizing second. For example, before explaining the fundermental concept of "molecular motion theory", the teaching film "molecular motion theory" was broadcasted. After watching the film, students, usually can quickly grasp the basic points of the microscopic model of matter under the guidance of the teacher. Further explanation is not needed.

C). Explaining first, broadcasting second. Some subject is unfamiliar to students. For these subjects, the teacher should first tell the students the basic content of the subject and the requirment of observation, explain the theory involved briefly before broadcasting the film. For example, when observing the critical phenomenom, the teacher should broadcast after explaining the basic theory of critical phenomenom and the characteristics of the phenomenom, calling the attention of the students to the changing process of the crooked liquid surface, the change of the height of the surface, critical milky light and other phenomenom. After the video is finished, the teacher should again make a summary of the phenomenom. Only after such repetitions can the students get a deep impression. If the broadcasting is given before any explanation, the students may fail to observe the most essential points.

D). Stage summary.

After a chapter or a topic is finished, a summary film may be used. We may assemble several phenomenom of same category or a series of phenomenom with close relation together to deepen the impression on the students and to enrich and broaden the students' knowledge. As in the film "Standing wave", we assembled the phenomena of standing wave on a string, in an air column, on a wooden plate, and on a membrane together and we show their relation with various musical instruments. Another example is the film "beat", we used tuning fork, rotating vector method, oscillography, computer drawing to demonstrate the "beat" phenomenom. So that the students can not only see the resultant curve, but also the resultant sound, and also learn the various considerations in designing the experiments.

E). Film in combination with demonstration experiment. Although video films have many advantages, students can only see the pictures rather than the real objects after all. So it lacks the feeling of reality,students usually hope to see the real objects, andpersonally take a hand in the work. So generally we not only show the film, but also show the real instruments or let the students see the demonstration experiments in the demonstration laboratory. Through this combination the advantages of both ways are brought into play and each become a supplement to the other.

F). Video films may be used in the presentation of the principles, structures and the operation of various apparatus. For some complex and precision instruments, it is difficult to understand all these by reading the illustration in the book, and unsuitable to let the students manipulate such instruments before they understand them thoroughly. For this reason, we have made some video films. In a film, we can explain while conduct, disassemble the instrument and reassemble it, can magnify some small components, and may show the instruments from different angles and different sides. A short film can give the students a basic understanding of the principles, structures and the adjustment process of the instruments, and make good preparation for their own operation. The films "Michelson interfereneter" and "the principle of light spectnometer" are examples of this kind.

III. How to make a good teaching video film.

For the TV films to be welcomed by students, to be taken seriously by the teachers, and to play the various parts described above, the most important prerequisite is some good TV video films as well some necessary facilities. A good teaching film should have the following qualities: colsely related with the teaching subject, conspicuous experimental pheonmenom, scientifically precise and aesthetically beautiful, concise and short.

Then how to make a good film?

A). Proper choose of the topic.

There are many demonstration experiments in fundamental physics, what to choose as a film topic? We generally choose the following kinds of topics: difficult and important subjects in textbook, experiments with little visibility or difficult to observe, experiments which need higher conditions phenomenon which is difficult to catch.

B). The basic content of a teaching film is the demonstration of a phenomenon with experimental apparatus. But it should also contain some related phenomenon rarely observed under common conditions, and the application of the physical laws involved in the scientific research and dailylife. These contents may enable the students to get a deeper understanding of the basic physical laws, to have wide vision and rich knowledge.

To do this extensive materials must be collected, we may take and expract from a film or TV news about the new achievements of technology and scientific research, we oftenwatch a lot of films or travel a long way for an extract of several seconds.

C). Deliberating design and use the advantage of TV video effetively.

Each scene must be carefully designed, and have several trial ones. For example, we should consider from what direction, in what angle the scene is to be taken. How to arrange the view to see both the global picture and local details. How to display the experimental phenomenom and the reading on the instruments simultaneously. To use what technique to ensure the good effect and the feeling of reality. How to combine the scientific preciseness with aesthetical beauty to promote the appeal, we should even consider whether the colours of the instruments, the table cloth and the background are harmonious. Every shot should be disculled, tried again and again until the ideal effect is obtained.

D). Teachers should closely coordinate with the technical personnels doing these work. The teacher must edit and direct the film himself, and the technical personnel must understand the intention of the teacher. Only with such coordination can the ideas about the teaching of the subject be implemented in the preparation of the film, and finally get a film closely related with the teaching of the subject, scientifically precise, aesthetically attractive, and has high quality both in the desing of the content and the application of various film techniques.

The process of teaching consists of several parts: lectures, exercise classes demonstration experiments, TV vides, student experiments etc. No parts may be weaken. We should not only exploit the TV video efficiently, but also pay attention to the coordination of the video with other teaching methods, to fulfill the teaching task satisfactorily.

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STRIVING FOR COMPILING THE AUDIO-VISUAL TEACHING MATERIAL ON PHYSICS

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Audio-Visual Teaching (A V T) is an important method in physics teaching. The teaching experience shows that the human beings rememberance obtained from Audio-sense my diminish to 70% after 3 hours and to 20% after 3 days. If you see both Audio-Visual methods at same time, the rememberance may diminish to 85% after 3 hours and to 65% after 3 days. This figure has proved that the "A V T" by using TV records and films is essential to physics teaching and is also important for improving teaching efficiency.

Through showing TV records, the remote and dangerous physical phenomena as well as the micro-phenomena can be demonstrated in the class vividly, which makes up the shortages of the oral explanation, reduces the difficulties of the writting on blackbord, improves laboratory conditions, enlarges student vision field and enriches student's acquaintance. Moreover, in our time, owing to the development of science and technology, limitation of teaching hours and the requirement of vivid study, the traditional teaching form, the method of using chalk and oral explanation must be reformed, and the Audio-Visual mediums must be adopted to increase teaching efficiency.

Since 1980, relying on our own capability, we have duplicated some foreign physics teaching films and compiled dozens of physics TV records, including «Maxwell's Theory and Electromagnitic Wave». «Reflection of Light». « Optical Fiber » « Interference of two light Beams». «Diffracting Gratting». « Scattering of Light » etc.

Up to date, nearly a hundred films, TV records, cartoons, dealing with many physics subjects, have already been compiled and exchanged in dozens of domestic universities, and 40 of which have been published by the Central Publishing House of Audio-Visual Teaching Material.

When we compile the Audio-Visual Teaching Material (A V T M), our first aim is to solve the major difficult problems in the general physics teaching such as moment of momentum, vibrations and waves, electrostatic field, Lorentz force, abberations, interference of thin films, polarization of light etc. All of these are fundamentals in general physics and some of which are too abstract to understand for most students. We try to make the students understand the material easily by means of enlarging phenomena, actual states, clear and accurate demonstrations, vivid cartoons.

Sometimes, there are some contents, which are not worth to teach clearly and not possible to demonstrate, such as the "Optical Fibers". We compile it as teaching material of record for consulting to enable the teacher to choose. This can help the teaching actively. "Optical Fiber" is a newly emerging scientific branch. Their primary pattern was explained in the class, but could not be opend out. We embarked in the conception, collected many domestic achivements dealing with "Optical Fiber". After having watched the record, the students obtain the new deep impressions. In this record, the automatic-focussing optical Fiber is introduced in detail, which makes the students understand the view of "Optical path" and "Fermats Principle" further. This record has been appiled in many universities.

Some present teaching, including the explanation of some instrument's construction and some experiment operations, can be recorded to be used frequently. It can not only prevent the teachers from repeating explanation, but also make students fully understand at a glance of it and so it is most welcome by students.

The teachers who make "A V T M", have to study the material deeply. This is a creative work, as they must master the basic conception accurately in accordance with the teaching requirement, the new knowlege must be studied, the experiments and excellent designs must be done, teachers need pay out painstaking effort to make the "A V T M". So a rule was worked out in the Education Ministry" The Audio-Visual Teaching officers and teachers should record their working load in accordance with the term of the document for teachers and cadres, in Education Ministry No. 011 the Audio-Visual Teaching material and accomplishment should be treated as same as the words teaching materials and scientific researching accomplishment. And the teachers should be praised and encouraged by giving prize according to the actual state".

The styles of "A V T M" made by us, are rich and various. Some of them are a complete experiment dealing with a certain topic or subject. Generally speaking, the film or TV program does not last over 0.5 hour. For the TV record, our first demand is that the "A V T M" should correspond with the scientific principle, the contents should be accurate. Next, the record should be vivid and interesting, and some proper music being fitted into the record.

The conditions, using "A V T M" in many universities, are better and better. The teachers' initiative, using and making "A V T M", is higher and higher. A variety of producers and co-operative departments that make "A V T M" are appearing in China. We are sure that more and better physics "A V T M" will be published in the near feuture.

Reference:

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PRELIMINARY DISCUSSION ON THE FUNCTION OF VIDEO RECORDINGS IN PHYSICS TEACHING

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Abstract

Since 1980 we have explored the function of the modern teaching aid—video recordings in our physics teaching with the aim of developing the capabilities of our students.

From the principle of the theory of knowledge, logic and thought, information transfer and pedagogy the function of video recording are discussed in the following four directions.

1. Turning abstract theories into concrete images, indirect experiences become direct;

2. Helping students with their transition from thinking in images to abstract thought;

3. Improving process of educational information transfer and control; and

4. Stimulating students' interest in learning and strengthening their memory and consolidion of knowledge.

It is hoped that this paper should be delivered with the accompanyment of excerpts from the following video educational recordings:

(1) Principle of Superposition and standing waves,

(2) Michelson Interferometer,

(3) The Principle and Applications of Atomic Spectra,

(4) Brownian Movement,

(5) The Motion of Electron in an Inhomogeneous Electric Feild,

(6) Angular Momentrm.

As a natural science, physics covers a wide range of knowledge, from the universe to the elementary particles. Much of concept of physics is very abstract. In order to make abstract theories more vivid and tangieble, since 1980 we have produced and translated some video educational recordings to explore ways of adopting modern teaching aids in physics teaching to develop students' capabilites. In this paper I would like to discuss some aspects about the function of video educational recordings in physics teaching.

1. Video educational recordings turn abstract theories into concrete images, indirect experiences become direct.

Teaching and learning are a process in which students learn under the guidance of their teachers and through their own activities to master cultural and scientific knowledge, develop their cognitive powers and gradually come to understand the objective world. It is, in essence, a process of cognition. What students learn in this process is the cognitive results that their forerunners have accumulated, in the form of indirect experiences and always are bookish. It is well-known that the knowledge movement of mankind is always from perceptual to rational. For this reason the teaching and learning activity should match with the knowledge movement of mankind. That is why when organizing a lesson, teachers usually begin with vivid and tangible phenomena from which theories are deduced and are used to account for typical examples.

Video-teachnique can make full use of the audio-vision to explain the teaching contents. Like demonstration experiments, it provides students with directly perceived material. Specific objects act directly on the students' senses in the form of shapes, colours and sounds. Video recordings have also such advantages as short production period and easily controllable in reproducing images suitable for use in a physics class.

For example, when explaining the formation of standing wave, the teacher would tell his students "The standing wave is the superposition of two waves of equal amplitudes and frequencies travelling in opposite directions with the same speeds". In general when we explain this principle, we just draw figures on the blackboard. It will be not only time-consuming but also too abstract. After showing this video educational recording, students can analyse the figure in the textbook and understand the concept by themselves. (shows an excerpt from the video educational recording "Principle of Superposition and Standing Wave")

The video recording can change static images into moving and make abstract concepts concrete and tangible. The students can derive the equation of standing wave according to the superposition principle which they have learned earlier, thus changing indirect experiences into direct. In this way, students will grasp scientific knowledge in progressive manner. At the same time, their scientific method of thinking and cognitive power are also developed.

2. Video educational recordings help students in their transition from thinking in images to abstract thought.

Directly perceived images are important links to students in obtaining perceptual knowledge, but the purpose of using these images in teaching is to help students to get rid of images and proceed to thinking in terms of generalized truths and laws. Man's thought goes on through the cerebrum. The work system of cerebral cortex is devided into two halves with the left half for the image thinking and the right half for the abstract thought. Only if these two halves work together can the function of cerbrum play fully. In their brains the students acquire new concepts and knowledge.

In physics teaching the gradual transition from real objects to directly perceived forms of symbols, charts, circuit and ray diagrams and characteristic curves and so on should be achieved. It is actually leading students from thinking in images to abstract thought. This is a very important stage in students' acquisition of knowledge. In the traditional way of physics teaching, after students have been shown directly perceived object in demonstration experiments, the teacher gives some oral explanation and draws charts and curves. The result is that the students are still not clear about the inherent relationship between the real objects and the images. Now, with video technique the directly perceived from of real objects can immediately shift to symbols and charts. This benefits students' active thinking.

We used this method in the video educational recording "Michelson Interferometer" (Shows on excerpt from the recording). The ray diagram shown above is induced from actual light routes and it is easy for students to get a deep understanding of the inherent relationship between the two.

Video educational recordings not only lead students from specific perception to thinking in images by showing image of real objects on the screen, but also help to develop thinking in images further to abstract thought. For example, it is often very difficult for a beginner to move from the wave-particle duality of light to establishing correct photon model. Students can get the particle concept through Einstein's theory of photoelectric effect and understand the wave nature from such phenomena as light interference, diffraction, and polarization. But how to combine the two in a physical model of photon? Some beginners understand the photon which is wave behind the particle, others seperate the two. Now let's see this excerpt of a video recording please. (Shows an excerpt form "The Principles and Applications of Atomic Spectra"). In the video recording, the physical model of small trains of waves is used to help students form the correct abstract concept. It shows not only the wave property, but also quantization of photon energy ($E = h\nu$). At the same time it also provides rudimentary Knowledge of coherence of light.

Again, let's now see demonstration of Brownian movement. (Shows an excerpt form "Brownian Movement".) From these two examples we see that with video recordings, the limit of time, space macroscopic or micrascopic is surmounted. It can effectively provide students with perceptual material, enlarge the range, enrich what is directly perceived. The contradiction between direct and indirect experience in physics education is thus satisfactorily solved. Theory and practice are more closely linked. Students can more quickly complete the transition from perceptual knowledge to rational knowledge and have capability developed.

3. Video educational recordings improve educational information transfer and control process.

Education is an activity of passing knowledge and skill. According to information theory, knowledge and skill can be regarded as information.

Therefore, education is a process of information transfer which involves means, approaches, methods, and contents. The effect of information transfer depends on the means and methods adopted. Inappropriate means and methods are less likely to bring about satisfactory result. The efficiency of educational information transfer and the accomplishment of education tasks are directly linked with teaching means and methods.

Viewed from Bavlov's theory of conditioned reflex, the traditional way of teaching has usually been information transfer through a secondary signal system. Wthat is more, with face-to-face teaching, the channel for information transfer is both narrow and short, resulting in low efficiency. In contrast, the audio-visual method makes use of one's primary signal system to produce strong stimuli and better effects.

Here is an example. It is impossible to observe the paths of electrons moving in electric field. Due to limited time in class, mention is made only of the relation between the direction of electrastatic force in electric field and the line of electric force. The motion of electrons in various inhomogeneous electric fields is often left to students themselves to deduce by analogy. Because of differences in students' level of intelligence, it is unavoidable at the beginning stage that some of them will misunderstand the motion of electrons as along the line of the electric field. If this excerpt is properly shown in class, any misunderstanding on the part of students can be corrected by themselves. (Shows an excerpt form "The Motion of Electrons in Inhomogeneous Electric Field".) In only two minutes the excerpt shown above gives students a lot of information not only about the electrical force and motion of electrons, but also the distribution of lines of electric force between two barrel electrods as well as the converging function of electrostatic lens. The information channel is thus broadened and lengthened. With only two minutes part of students can understand a lot. Those who have not understood thoroughly can further study from the directly percelived images. In this way, not only teaching efficiency is incresed, but also the foundation is laid for further improvement of teaching quality.

4. Video educational recordings can stimulate students' interest in learning and strengthen their memory and consolidate their knowledge.

In the process of teaching, while passing on knowledge, developing students' intelligence and creating talent, teachers should give them the initiative for learning. What is of utmost importance is to arouse their interest in learning which is very important in organizing their active study. Educators, whether ancient or modern, Chinese and foreign, all stress interest in learning. Einstein, the giant of science, regarded interest as the best teacher. Only when interest in learning is stimulsted, can we hope to raise their thirst for knowledge, their will power to think actively and explore the truths.

Students' interest in learning can be aroused in many ways. Video educational recordings have the great advantage of reproducing objective objects, without any limit in space or conditions. A good video educational recording, with an excellent combination of being scientific, novel, entertaining, infuitional and artistic, has very strong appeal to students. In the past, when they were taught angular momentum without using real objects or video recording, students felt it too abstract to grasp. Now we have a video recording on that subject. (Shows an exceprt from "Angule Momentum.") After they have found and felt the interst but no yet known phenomenon, students begin to ask questions. Their interest in learning is then made full use of as a basis upon which they can study and solve the problems.

As students solve their puzzling problems, it means they have found the truth. In other words, they have acquired knowledge. Here is another example. A difficult point teaching physics is interference of constant dip. The computer animated cartoon which makes clear the cause-and-effect, turns the abstract into visible images. And what otherwise might be difficult has become simple and easy. All this has been well received by our students. (Shows an excerpt from "Michelson Interferometer".)

What the above video educational recordings have provided is mostly fresh and vivid images of objective objects. Upon gaining these direct experiences, students will think in abstract thought and think things out for themselves in studying problems and search after knowledge, thus from the foundation for grasping and securely memorizing knowledge. Memory of this kind is called random memory in pedagogy. Different from conscious memory or recitation, random memory is more secure as it is based on deep interest, active thinking and some times engrossment in learning. The more actively one uses his imagination, the stronger will be his random memory. Of course it can only be built on the basis of students' own strenous effort. If video recordings are well edited and produced, they will more deeply affect the students, the more steady-fast their memory will be.

The above preliminary experiences show that video educational recordings, like demonstcation experiments, are a very important means in physics teaching to enable students to acquire perceptual knowledge. Although it cannot replace classroom teaching, it has an active role in improving teaching efficiency and quality.

Teaching is an art. Both teaching and learning have no limit. A great deal remains to be done, we must continue to explore the possibilities of video educational recodings for physics teaching.

Thanks!

THE MECHANICAL UNIVERSE: VIEWING PHYSICS THROUGH THE WINDOW OF TELEVISION

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The Mechanical Universe is a calculus based course in physics intended for non-traditional college students. The series consist of fifty-two half-hour programs covering mechanics, heat, electricity, magnetism, relativity, optics, and modern physics. The video offers an exciting array of audiovisual resources for classroom instruction: closeups of implicated and expensive experiments; exciting, entertaining animation sequences that make abstract concepts and mathematical processes understandable; historical reenactments that provide an intellectual and philosophical basis for the idea of physics.

The Mechanical Universe is based on the physics course developed by David Goodstein and introduced at the California Institute of Technology in 1979. Twenty six programs covering classical mechanics are currently shown through the Public Broadcasting Stations in the USA. The background and goals of this project will be discussed and a sample television program from the series will be shown.

THE MECHANICAL UNIVERSE: NEW AUDIOVISUAL RESOURCES IN PHYSICS EDUCATION

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A new perspective on introductory college physics that uses the magic of television is currently being developed -- The Mechanical Universe. Funded by the Annenberg/CPB Project and produced by the California Institute of Technology in conjunction with the Corporation for Community College Television, The Mechanical Universe is a calculus based course in physics intended for non-traditional college students. The series consist of fifty-two half-hour programs covering classical mechanics, heat, electricity, magnetism, relativity, optics, and modern physics. Through liberal use of computer animation, historical recreations, applications to everyday phenomena, this project aims to use effectively the television medium as an educational tool. Additional funding by the National Science Foundation has supported adaption of the television programs for use in high school courses. A sample television program from the series as well as a program adapted for high school use will be shown.

BASIC PHYSICS FOR BIOLOGY STUDENTS AT THE UNIVERSITY OF SÃO PAULO

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The two semesters course (240h) on basic Physics for the students of the Institute of Biosciences of the University of São Paulo was introduced in 1971. The initial program included Classical Physics and some topics of Modern Physics. The translated text books by J. Orear1) and R. Resnick and D. Halliday2) were adopted or recommended, from 1971 to 1977. Only in 1978/1979, some applications in Biology were introduced by using the text book by A.H. Cromer3) which was in English.

The approach adopted during all those years did not differ very much from the one followed by the traditional courses of Physics. This means that, firstly, the bases of physical concepts are given and then used in some applications. Three of the authors had participated in this scheme in different occasions and detected some problems: lack of motivation from the majority of the students, strong prejudice against Physics and Mathematics, a very weak and unsatisfactory basis on Mathematics, a too extensive program and inadequate approach for preparing future researchers in life sciences and general sciences teachers in the elementary school.

In 1980, we began the reorganization of the theoretical part of this course. In this new proposal, great emphasis has been given to topics related to life sciences with an essentially interdisciplinary and phenomenological approach. The main purposes of these modifications were:

- *to motivate the students and to demonstrate that Physics can help them to understand a large number of natural and everyday life phenomena;*
- *to modify the students' attitudes and prejudices that may be transmitted to their primary school pupils;*
- *to introduce some fundamental scientific concepts as well as technical informations, in order to help the students to understand some new technological and scientific developments.*

A text book4) which took into account the main aims and the actual background of the students has been especially written to be used in this course. In some occasions, detailed demonstrations of formulae starting from basic concepts are skipped. Instead, a discussion on the physical plausibility and interpretation of the parameters are given.

The selected basic topics discussed in the first semester are: Radiation Physics, introduced at the beginning of the course to motivate the students; Energy; Forces in the Human Body; Animal Flight and

Biological Scaling. In the second semester: Wave Phenomena (Hearing, Compound and Human Eyes); Fluids in Biological Systems (Respiration and Circulation); Electrical Phenomena (Cell Resting Potentials and Propagation of Action Potentials); The Limit Velocity and the Measurement of Time.

As far as the laboratory classes are concerned, the purpose is the initiation of the students to the experimental work in a general sense. Therefore, the main objectives of the laboratory classes are:

- *to organize an experimental work: quality control and tabulation of data, drawing of graphs, evaluation of experimental errors, analysis and interpretation of results;*
- *to observe some phenomena which are difficult to be demonstrated during the lectures;*
- *to show to the students how to be critical of what they do and to be aware of what can be done;*
- *to perform at the end of the course one whole experiment in Physics, from the definition of the phenomenum to be studied to the statement of relevant conclusions, including the careful preparation and execution of the experiment and data analysis;*
- *to write individually critical and formal reports.*

With these objectives in mind and taking into account the availability of the equipments in the Institute of Physics, 5 or 6 experiments have been prepared for each semester. Whenever possible, the experiments followed the topics taught in the theoretical lectures. This fact strongly motivates the students.

Some experiments are divided in two parts: in the first part, the students observe and analyse the physical phenomenum; in the second part, based on the studied phenomenum, the same equipment is used to measure a quantity of biological interest. These experiments are: calorimeter and the measurement of the metabolic rate of a hamster; light diffraction and the determination of the human red blood cell diameter; experiments in geometrical optics using lenses and the study of a simple model of human eye; oscilloscope and its use for the study of sound waves.

Other experiments are directed to the observation and confirmation of the theory: Absorption of Ionizing Radiation by Matter; Emission Spectrum of the Hydrogen Atom and Solar Energy Conversion.

The selected experiments are listed in tables I and II.

Table I: Experiments performed in the first semester.

1. Measurements with Geiger-Müller counter.
2. Emission spectrum of the hydrogen atom.
3. Statistical analysis: measurements of height and mass of the students.
4. Electricity: measurements of currents and voltages in simple circuits.

5. Torques and forces in the arm.
6. Simple project.

Table II: Experiments performed in the second semester.

1. Viscosity, osmosis and surface tension of fluids.
2. Diffraction - Erythrocites diameter measurement.
3. Vibrating string.
4. Oscilloscope.
5. Thin lenses and the human eye.
6. Project.

The laboratory classes, structured as described, in sessions of 4 hours every two weeks, have been well accepted by the majority of the students. The reports are prepared as homework.

A manual[5)] for the experiments has been written. It also contains an introduction to the evaluation of errors and the proper use of significant figures.

After five and half years of experience, we can conclude that:

i) *it is possible to teach Physics within a framework that takes into account the characteristics of the students and their specific needs, as well as their interests;*

ii) *it is feasible and one can obtain good results from a basic Physics course for Biology students, which has an interdisciplinary and phenomenological approach, developed in a life sciences context with very little Calculus.*

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A GRADUATE COURSE ON SCIENCE TEACHING

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The formation of competent teachers for all levels is a general concern but it becomes particularly important and complex in developing countries. The existence of graduate courses in the area of teaching can be basic for this purpose but very often such courses cannot be established mainly due to the lack of tradition in science teaching research.

A graduate course on Science Teaching (option Physics) is in operation at the University of São Paulo(USP)since 197[illegible],under the responsibility of two university units: the Physics Institute and the Faculty of Education. The initial purpose of this course was to provide formation at graduate course level for students with an undergratuate degree in Physics who would teach at secondary schools.

The main reason was the crises undergone by science teaching in the 50 and 60 decades which resulted in the preparation of Physics teaching projects in some countries. Also at the Physics Institute of the USP, several teaching projects have been developped with the participation of secondary school teachers and University staff members:

- Physics Teaching Project (PEF) which included a text and a low cost kit for experiments.
- A set of educational super-8 films on Center of Mass and Energy.
- An individualised programmed course for the University basic cycle based on the Keller Method.

These projects followed the tendencies of that time without really constituting well defined lines of research.The teams were gathered according to the concerns and interests of Physics teachers who would be willing to spend part of their Physics Research time in this "new Physics Project"although not always receiving credit from the more conservative investigators.

At the end of these projects it became clear that a better organization and theoretical deepening in teaching problems could only be accomplished through studies and staff involvement in teaching research.

A graduate course on the teaching of Sciences (option

Physics) was then established with the participation of staff which had been working in projects and courses in several university units that had somehow served as the basics for the work that had been done. Such courses were offered mainly by three University Units: Education- Piaget Theory, Fundamentals of Teaching; Psychology- Programmed Instruction Techniques (Keller Method), Behavior Principles and Physics- Classical Mechanics, Quantum Mechanics, Classical Electrodynamics.

Due to administration conveniences at the USP the units which became responsible for the graduate course were the Physics Institute and the Faculty of Education, although optional courses could be taken at any other USP unit.

The first advisors for graduate students were investigators from the various groups. Some of them had experience in Physics research and considered that it would not be very difficult for then to transfer their experience to the field of Physics teaching. Therefore at the beginning of the course graduate students and advisors had a similar level of knowledge about the subject therefore the work was shared by people who at the same time had to learn and contribute for the group.

Most of the advisors were from the Physics Institute working in Physics research, especially Nuclear Physics. Their experience in Physics teaching came mainly from their activities 'at the University undergratuate courses. Some have had a participation in the projects mentioned above. Students who had a similar experience but did not have a PhD degree were enrolled in the course and started to take the subjects that composed the curriculum.

Therefore the course was characterized by gathering subjects from the several USP units and by a pragmatic concern with the production of teaching material to be used in the classroom. The change to a truly interdisciplinary character is taking place progressively through research on education and the interaction with teaching institutions of all levels. The various activities which were developed during this process contributed effectively for the personality the course has today.

Teaching and Research Activities

One kind was the preparation of theses which in each case required a research on some specific problem, thus forcing the people involved to deepen their knowledge on adequate theories and methodology as well as on the Physics Content.

The cooperation of external specialists was obtained during this phase.

Both students and advisors were facing a common problem usually connected with evaluation or the production of projects as shown by the first theses concluded in 1976, four years after the course started (see Appendix 1).

The evolution of theses contents during the following years is interesting, as shown in appendix 1. The first students that concluded masters theses helped to advise the next students. The theses subjects then became more authentic and meaningfull in the Physics teaching context tending to a situation where the Education and the Physics contents merge so as to combine coherently the structure and nature of the different contents involved.

The second important activity was a series of courses given by foreign visiting investigators who were especially invited to give optional subjects in this interdisciplinary area. The subjects were mainly in the areas of History of Science, Intuitive Concepts, Evaluation and Curriculum. The criterion for the choice of courses and invited professors was connected with the interests of local groups that were willing to woork with a certain subject. Appendix 2 shows a list of these courses with the corresponding visiting professors.

With the continuation of studies and research on the subject which was dealt with in these courses, members of the Brazilian staff started to offer similar courses in the following years; these courses are listed in Appendix 3.

Usually the members of the local staff who were giving courses were doing research work in a related area and this connection was profitable for both activities since the course would become more intersting and the research would gain depth.

It would be also desirable that all the subjects offered by each University unit for this graduate course were integrated under the essential idea of interdisciplinarity. In fact there was an attempt of proposing that the Quantum Mechanics Course which is obligatory for Masters students was offered with a conceptual and historical approach similar to that used in

Prof. Rudinger's course whose lectures were based on Tomonaga's text "Quantum Mechanics".

However other Physics Institute professors did not agree to follow this approach and the course continues to take part in the curriculum but in its purely formal aspect.

Weekly seminars were also carried out as the third regular activity and they were important for opening discussions on general problems of teaching, applied methodologies, research proposals, conference reports, etc. The people invited to give the talks had different levels of knowledge and specific experience from professors, investigators to graduate students who were often invited to report their work. An effort was always made to involve students and advisors stimulating them to suggest subjects for the seminars.

The fourth activity, although not directly connected with graduate courses consisted of (recycling) courses that the Physics Institute has been offering for secondary school teachers. It is precisely through this activity that it is possible to keep a close contact with this level of Physics teaching. Most of these subjects are taught by staff members doing research in the area of Physics teaching they tried to involve graduate students as colaborators. These courses have multiple purposes: a discussion of the Physics contents (formal structure, conceptual evolution and tecnological applications) aiming to the improvement of the teachers knowledge; the discussion of questions on the learning of Physics (intuitive knowledge, social situations of students, etc.) the discussion of adequate teaching methodologies for improving the relation between teachers and students; the production of material for experimental teaching.

All these different activities have been essential for consolidating the graduate course and for the development of research.

The structure of research groups came with time and new lines of investigation were defined. Part of the research work resulted in Masters theses.

The research that is carried out presently is concentrated in three main groups: intuitive concepts, history of science and curricula project and production of material. Students engaged in these groups develop contents related to these lines of research for their theses working on the aspects of methodology of content analysis, evaluation and planning of instructional material, critical study of the history of science study and application of theories of learning.

Up to the present, 36 Masters theses have been completed covering several lines of research. Those completed after 1980 show already a tendency of gathering around the three lines mentioned above; some examples are shown on appendix 1.

A new line which deals with the use of microcomputers in teaching is being established but no research has yet been concluded.

Along these thirteen years the course has been acquiring its personality.

The lines of research which have been defined are connected with really interdisciplinary subjects that are offered in the course. We consider that conditions are now favorable for the establishment of a graduate course in a PhD level, some of the masters in Physics teaching later obtained PhD degrees in Education or Physics thus formally acquiring the capacity to be advisors. Therefore, the group of advisors has gained some specialists with time.

The course has presently 10 advisors and about 60 students, all involved with secondary school teaching. It is the only course of the kind in Latin America. Some of the 8 to 10 students that enter every year come from other regions and the course offers 18 scholarships. The course operation has already reached a steady state and should go through a general discussion aiming to a revision of the curriculum and the establishment of the PhD level.

APPENDIX 1

THE FIRST THESES: PROJECT EVALUATION AND PRODUCTION OF MATERIAL

The Physics Teaching Project (PEF)- Mechanics I in a Programmed Individualized Course - 1976

This work presents an experimental study of the application of the Physics Teaching Project - Mechanics 1 in a personalized system of instruction (Keller Method).

In the first stage the purpose of this experiment was to verify the applicability of the Project in this method of teachin In the second stage the purpose was to evaluate the teaching materia of the Mechanics 1 Project by means of analysis of the learning situations programmed for the student. Several limitations of th material have been identified and modifications for their eliminat have been suggested.

Students Performance Analysis in view of the Physi Teaching Project Goals - 1976

In this work the Mechanics section of the Projeto de Ensino de Física (PEF) is investigated. Initially the program sequences are analys and the intermediary and final objectives of the text are identified.

Three important behaviours for a Physics teaching progr at the secondary level are selected: to mesure with precision; to calibrate instruments and to analyse stroboscopic photographs.

In order to analyse the bahaviour of students in relat to these objectives, discursive tests are constructed.

Answers to these tests are analysed in connexion with the program sequences and conclusions about the PEF program are reach

An Electricity Course aiming to the transfer of Learning 1976

This work discusses the Transfer of Learning and the importance of incorporating it as an explicit objective in scientific curricula. The first part treats the concept of transfer according to the various theories and indicates the point of view which we are adopting which respect to this subject.

The "Projeto de Ciências Mobral/Funbec" is described, especially the Electricity Unit. The curriculum has been designed for persons who have just gone through a literacy training program. The Electricity Unit is almost self-instructing and comprises written material a simple experimental kit containing bateries, electric bulbs for a touchlight, a small model of a house made of cardboard, electric wire, etc. The content of the unit concerns the electric installatio of a house.

The last part describes the evaluation of the Electricity Unit, regarding Transfer to everyday life. After the Course, the students are requested to perform the electric installation of a small house, using materials for a real wiring.

Analysis of the FAI Project a Proposal for a self instructive Physics Course - 1977

This work describes an experiment beginning in 1970 in the field of physics teaching for second grade students, through the elaboration and utilization of the "Teaching Project FAI" (auto-instructive physics) being its purpose to verify the viability of the utilization of an auto-instructive system, based on educational technology principles.

A succint analysis is made of teaching conditions found in the majority of the second grade schools and its aspects. It is emphasized the necessity of using active teaching methods in which the student and not the teacher holds de center of the educational system.

Some results obtained in terms of acceptance of the Project FAI are shown

CURRICULA PROPOSALS AND CONTENTS

The teaching of Physics and Community Problems - 1981

This work presents a way of keeping records on educational experiences specially science courses concerned with community problems. Initially the enunciation of educational assumptio a theorical frame work, finally the experiment is described and analyzed. A science course for third year students of a primary schoo in the town of São Paulo do Potengi in Rio Grande do Norte is describ dealing with the problems of water supply. During this process the following points were identified as import for proposal of science teaching adressed to community problems: study of community; methods of presenting the science content classroom methods and method of approach to the community.

A Course on Physics of the Environment - 1981

In this study we report the programation's experience of the Física do Meio Ambiente (Environmental Physics) courses, given to students of Physics in the Universidade Federal do Rio Grande do Norte, through the years 1976 to 1978. We try to consider what this experience meant regarding the proposition of its objectives.

Considerations are done regarding the objectives produ and the characteristics of the activities.

From what that experience had shown us, we pointed some important aspects that should be considered to the proposition of a Física do Meio Ambiente course given to students of Physics, especially in the State of Rio Grande do Norte.

Reflections on the Secondary School Physics Curriculum in Brazil - 1985

The curriculum of physics in Brazil retains the characteristics appropriate for the times when secondary schools were restricted to the preparation of a few students for University places. However, the motives for a secondary school adapted to the needs of a new society ask for curricula more concerned with general education.

In the first part of this study the physics curriculum is viewed in its evolution, from introduction in the schools to its present state of inadequacy. The second part tries to explore and organize some proposals for the development of new science curricula. These ideas are then used, in the last chapter, in an essay on the definition of the goals and content of a particular curriculum.

Formation of Science Teachers - An Educational Project Developed in Guiné-Bissau - 1982

In opposition to the idea of "training" science teacher the task of teacher's formation demands an accurate study of some features wich would be otherwise neglected.

A course like this has taken place at Guiné-Bissau and revealed these features, namely, the need of an effective experimental praxis and the development of an unifying concept in the science teaching, as well as problems related to cultural overlap

On one hand, these points were essential to the conduction of the particular project in Africa, on the other hand they are clearly extensive to many brazilian contexts.

HISTORY OF SCIENCE AND DEVELOPMENT OF CONCEPTS

Teaching of Concepts: A Study of the origns of the second law of thermodynamics and the entropy concept from the 18th Century - 1985

The purpose of this work is to recover historical elements of the definition of the 2nd Law of Thermodynamics and the Concept of Entropy, in order to use them in the teaching of Physics.

Heat theories from the XVIIIth century-flogisto caloric - are discussed from the point of view of the main elements that characterize them as coherent, and different systems of thought about heat phenomena.

The concluded work is intended to provide subsidies to physics teachers training, supporting an approximation between pupils' and teachers' thought. We describe an actuall experience where these studies were used, a course for Secondary and High School teachers.

In conclusion, we comment on the development of the ideas related to 2nd Law and entropy, and on the historical studies for the educational context.

An Electromagnetism and Relativity Text Based on Structural Knowledge - 1985

We present a text concerning the relationship between Electromagnetism and the Theory of Relativity, at the level of the last years of a graduate course in Physics. We believe that the stud of this text will lead to a critical posture towards its contents. This is a necessary condition for the effective appropriation of the subject.

We examine the conceptual structure of the Theory of Relativity and argue that the part relative to the Electromagnetism can be presented in several different ways, each of then characterize by a world-view.

Intuitive Concepts and Knowledge structures - Study of spontaneous notions about light phenomena with 11-18 years old students - 1982

In order, to ascertain what are our students notions on light, as Guesne has already investigated, we interviewed 30 students from a public school who were divided in three groups, averaging approximately 11, 15 and 18 years old.

The subjects were individually submited to two differe types of interviews: directive and non-directive one.

Generally speaking, the spontaneous ideas expressed by our subjects were quite similar to those obtained by Guesne. Among them, we could notice that some phenomena are considered in a certain way, independents of light. The occurence of rudimentary models of physical phenomena related to light is due to the fact that the subject makes the readings of the experiment at the level of the phenomenon immediate perception.

Intuitive Concepts: Relation between force, velocity, acceleration and trajectory - 1985

In this work we presented some special problems on elementary mechanics to more than five hundred brazilian university student and analyzed the responses, trying to obtain informations about the conceptual apparatus used by these students. Interesting results were obtained: force as something that objects may keep in and expend; force proportional to velocity; trajectories being determined by the composition of forces or by the composition of force and velocity; acceleration and velocity with the same meaning; and force related to velocity through the relations "a= v/t" and F= m.a, what lead to the reasoning $v \neq \rightarrow a \neq \rightarrow F \neq$. Some of these results indicate an indifferenciation between kinematics and dynamics in the intuitive physics of the students.

Structures of Reasoning in Physics Entrance Exams t the University of Minas Gerais - 1985

Physics entrance examinations were analysed in respect to the quality of reasoning used by students in solving problems in a written examination. An analysis instrument based on Piaget's theory on the development of mental structures has been used.

Two types of results have been found: the first reveals the ability of a large and varied population such as the University candidates in solving Physics problems ; the second shows how the Physics content is taught at the secondary course and at parallel entrance preparation courses.

Students Energy Concepts - 1985

Many of the answers given by students to questions which are proposed to them on physical situations may involve a particular and often coherent conception on the subject, but usually covered by inadequacies and even incorrections.

The aim of this work is to establish a structure for this particular conception regarding to energy.

The question of research on these concepts is considere particularly on energy through the analysis of students answers to several questions on this subject.

The historical evolution of this concept is also summarized and an analysis is presented on how it is dealt with in physiscs textbooks.

At last, the alternative conception of energy, obtained from students answers, is related to the historical evolution of the concept and to the way they are presented in textbooks.

APPENDIX 2

- Topics of the History of Science in the 19th and 20th Cen
  Marcello Cini (1979)

- History and Philosophy of Science-Scientific Revolution 17th Century
  William René J. Shea (1979)

- The Birth of Quantum Theory
  Marcello Cini (1980)

- Spontaneous reasoning in Elementary Mechanics
  Laurence Viennot (1981)

- History and Philosophy of Contemporary Physics
  Michel Paty (1982)

- Topics of History and Physical Epistemology
  Michel Paty (1985)

- Classical Mechanics
  E. Rüdinger (1974)

- Statistical Methods in Experimental Physics
  Wayne M. Roney Jr. (1974)

- The Conceptual Development of Quantum Mechanics
  E. Rüdinger (1974)

- The Development of Piaget's Psychology
  Joan Bliss (1975)

- Teaching and Learning in Higher Education: Relativity
  L. R. B. Elton (1975)

- The Conceptual Development of Classical Eletromaghetism
  E. Rüdinger (1975)

SOME CONSIDERATIONS IN THE PLANNING OF THE GRADUATES FOR MASTER OF PHYSICS PEDAGOGY OF OUR UNIVERSITY

Su Gang, Liaoning Normal University, P.R.C.

We have long been considering the enrollment of graduates for Master of Physics Pedagogy. The present teachers are old, and various ways have been tried to find their sucessors, but in vain. The only feasible way left is to admit graduates to replenish the faculty in future. Through later learning, especially through learning Mr. Deng's instruction: "Our education is to face the modernizations, the world, and the future", we are clearly aware that we should not be short-sighted and that the enrollment of graduates should not be a makeshift arrangement. Our motherland is determined to build herself in the next few decades into a highly prosperous, modern powerful country with high level of spiritual and material civilizations, thus making absolutely necessary to develop with all-out efforts her educational undertakings, to bring up millions of primary and secondary school teachers of high quality, to train first-rate teachers and scientific researchers of disciplinary pedagogy, including those of physics pedagogy. There is no doubt that the first-rate teachers and researchers of disciplinary pedagogy are a determinative factor, and that it will be best if they hold higher academic degrees. So the importance of the present graduates of disciplinary pedagogy cannot be overstressed. Also, we must not lose sight of that it is in their generation that our motherland will join the ranks of the developed countries. Our science and technology, culture and education will be moving towards the world, too. This is a grand mission. They ought to make their contribution in this forward trend, and carry our physics pedagogy (both its teaching and scientific researches) to the world's advanced level. Under these circumstances, we must think carefully, all-sidedly, and deeply when we formulate the educational plan of the graduates, strive hard to well prepare them to forge ahead, to enable them to give full scope to what they ought to fulfil in future. To this end, we investigate and probe into (but only tentatively) the educational objective and the relevant measures as follows.

The educational objective of the graduates for the Master of physics pedagogy should be: to develop them in an all-round way—morally, intellectually and physically—to become the specialists fully competent for the task of physics pedagogy in schools of education and other institutions of higher learning, and to be creative in their researches of their speciality.

There must be some most important requirements and relevant measures for achieving this objective:

First, they must have deep love for and unswerving devotion to their work and speciality. This is the most fundamental prerequisite for achieving the objective. We must, through our educational work, do our utmost to encourage the graduates to develop a noble and lofty ideal: to be an educator with firm and unshakable dedication to, and boundless love for, the young people, to guide gently and be never tired of teaching, to spare no effort in the performance of his duty till his heart stops beating. Only if he has this spirit can he become an excellent teacher and researcher of physics pedagogy.

Secondly, they must have a good command of modern theories and methods of physics, including the principles and methods of modern experimental physics. That is to say, they shall be fully familiar with and deeply aware of the modern thoughts, theories, and methods of physics and get trained strictly and amply in these fields; they shall acquire a profound understanding of the essence of such thoughts, theories, and methods, and of the great significance and role of these in the formation of the scientific world outlook and methodology, and in the development of science and technology, culture and education of the world.

They should understand that physics is the pioneering science. It is physics that has played a decisive role in the successful struggles of atheism against theirsm, materialism against idealism, and dialectics against metaphysics, and will continue to do so.

They ought to understand that all previous industrial revolutions had as their forerunner the revolutionary progress of physics. The heat engine and electric machinery led to the rise and development of the Industrial Society and to the incomparable growth of the world's productive forces. The radio and electronic sciences have brought about the communications revolution and the productive process automation, widened and deepened the industrial revolution and further tremendously expanded the world's production. The electronic computer is inspiring the thought of the Information Society (also known as the Knowledge-Intelligence Society) and will play a decisive role in the successful construction of such a society.

The present principal scientific research problems of modern science and technology, such as that of electronic and optical computer, artificial intelligence, laser, optical fibre, new energy resources, new materials, molecular genetics, and genetic engineering, have a great deal to do with the thoughts, theories and methods of modern physics, some of them are the very objects of physics researches. It would be quite safe to say that it is impossible to be successful in all these researches without systematic, broad and deep knowledge, theories, thoughts and methods of physics. This is because physics deals with the most general, universal, and fundamental laws and ingredients of matter and motion—the essential foundations of every science and technology. Most important of all, physics provides a scientific world outlook and all-conquering methodological weapon. So every field of science and technology must regard physics as an indispensable and important foundation.

It is absolutely necessary and important for them to understand and grasp all those mentioned above, in view of which we offer the graduates such courses as follows:

1. Dialectics of Nature,
2. History of Physics,
3. Modern Theoretical Physics (including Advanced Quantum Mechanics, Field Theory, and some strictly selected new courses such as Theory of Dissipative Structures, etc.).
4. Principles and Methods of Modern Experimental Physics,
5. Studies in the Fundamentals of Physics (1).

Thirdly, they must have a good command of modern theories of psychology and pedagogy, and be able to apply such theories to the study of the specific rules and the laws of physics pedagogy. Modern psychology and pedagogy have made epoch-marking progress and are beginning to undergo at present the process of cybernetics, information theory, and systematology penetrating the scientific researches of psychological and pedagogical sciences. Such a combination will inevitably upgrade psychology and pedagogy to a completely new stage. We must lose no time and spare no effort to enable them to clutch at new, important facts and theories in these fields, to educate and train them to acquire the world's advanced psychological and pedagoical thoughts and viewpoints and to apply them to explore particular rules and laws of physics teaching and educating. At the same time, they shall study to master modern educational technology (such as electrical audio-visual aids and CAI systems, etc.) and to join modern educational technology and pedagogical theories with a view to reveal rules and laws of the formation and development of the student's knowledge, competence, and the world outlook. In the meantime, they shall learn and study foreign advanced physics teaching and educating experience and size up the progressive trend, catch up with the march of the time, move towards the world, forge ahead to meet still newer and greater challenges head-on!

In these fields, we offer the graduates courses as follows:

1. Educational psychology (it treats, among other things, Piagetian theory, etc.),

2. Modern Theory of Instruction and Modern Theory of Physics Instruction (2),

3. Principles, Languages, and Application of Electronic Computer,

4. Studies in the Teaching Methods of Modern Educational Technology,

5. Studies in the Experiments of the Middle School Physics,

6. Studies in Foreign Physics Education

Not only should the graduates study theories well, but also ought they to learn from the advanced middle school teacher's experience, to do practice teaching and educating in order to integrate theory with practice, to temper themselves in the teaching reality, to enhance their teaching ability and research ability, to write fine these on physics pedagogy. For this purpose we offer the graduates courses as follows:

7. Educational Survey (including listening to the advanced middle school teachers' experience report, instructional observation, interviewing the teachers and students, etc.)

8. Instructional Practice (including teaching in middle schools, accumulating teaching experience and gathering materials and data, learning to sum up experience, and enhancing teaching ability and research ability),

9. Instructional Reform Experiment (The graduates put forward prudent experimental plan beforehand, experiment with new teaching methods or subject matter, and seriously sum up successful and unsuccessful experience afterwards, thus laying solid foundations for their Master's theses.)

10. Middle School Physics Pedagogy practice (3).

Fourthly, it is very important for the graduates to acquire proper proficiency in foreign languages in the interests of realization of the educational objective. Only thus are they in a position to learn directly from advanced foreign experience and theory, to carry on international academic exchanges, to establish friendly relations in international academic circles. With this end in view, we offer the graduates two courses of foreign languages. We require that the graduates be able to make use of their first foreign language to read and write materials and literature, to exchange experience and achievements in scientific researches, that the graduates be able at least to make use of their second foreign language to read materials and literature.

Notes

(1) Such "studies" may be many-sided and important. For example, we may study "the Fundamentals" from the viewpoint of the curriculum theory, that is to say, we study the position and role of "the Fundamentals" in the complete curriculum of the middle school and how to coordinate physics with other disciplines to foster new gifted people; we may study "the Fundamentals" from the viewpoint of the instruction theory, namely, we study how to form in the students the scientific concepts and how to cultivate the students ability to analyse and solve problems on their own; we may study from the vantage point of advanced theoretical physics such contentious and interesting problems as the origins of frictional feress and on-electro-static forces, etc.; we may study problems of physics in astronomy, meteorology, geology (geophysical prospecting, etc.), chemistry, biology, with a view to help accelerate the progress of such sciences. It is obvious that to project well such a course is very important and difficult. We ought to make a monographic investigation and study. Now we can only highlight some aspects of it according to demand and possibility.

(2) Clearly, so christened as to emphasize two points, to emphasize the "general" theory of instruction on the one hand. Only by possessing abundant and solid fundamentals of general theory of instruction can the graduates solve particular problems of theory of physics instruction. On the other hand, to emphasize the "modern" progress of the theory of instruction so as to enable them to apply new points of view to solve new problems.

(3) It is an important required course taken by students majored in physics in higher schools of education in China. It consists of three main parts: theory of the course of study, middle school physics experimental techniques, middle school physics teaching practice. The graduates doing practice teaching in all three parts is necessary, but time may not permit. Stress may be laid on one part in accordance with demand and possibility.

DRAFT PROGRAMME OF THE GRADUATES FOR MASTER OF PHYSICS PEDAGOGY

Subject	Class Hours per Week in 3 School Years						Assessment Mode
	1st		2nd		3rd		
Common Courses							
Dialectics of Nature	4						According to Unified Stipulations
Foreign Languages	6	6	2	2			
Degree Courses							
Modern Advanced Theoretical Physics	4	3					Examination
Modern Experimental Physics		3					Examination and Achievements Inspection
Modern Theory of Instruction and Modern Theory of Physics Instruction		5					Examination
Required Course							
Educational Psychology	3						Examination
Studies in the Fundamentals of Physics			4	4			Examination
Principles, Languages, Application of Electronic Computer	3	3	3				Examination and Achievements Inspection
Studies in Teaching Methods of Modern Educational Tech.			3				Achievements Inspection
Studies in Middle School Physics Experiments				3			Achievements Inspection
Studies in Foreign Physics Education				3			Routine Work Check
History of Physics			2				Routine Work Check
Educational Survey			3				Routine Work Check and Achievements Inspection
Educational Practice			3				Routine Work Check and Achievements Inspection
Instructional Reform Experiment				3			Routine Work Check and Achievements Inspection
Middle School Physics Pedagogy Practice				3			Routine Work Check and Achievements Inspection
Degree Thesis					*	**	Reply in Argument

Optional Courses							
Epistemology and Dialectics							
Psychological Experiments Design							
Audio-visual Materials Fabrication							
Total	20	20	20	18			

* Thesis Writing

** Thesis Writing and Reply in Argument

ON THE TRAINING OF GRADUATE STUDENTS IN THE FIELD OF COLLEGE PHYSICS EDUCATION

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P.R.C.

In 1980 this school for the first time began to recruit graduate students in the field of College Physics Education. This was a new undertaking and we lacked experience. We, therefore, had to feel our way through. Up to the present we have admitted four batches of graduate students, eight of whom have already completed their studies, with six being awarded M.S. degrees. Now still working for their M.S. degrees are fourteen graduate students.

More than twenty universities and colleges across the country recruit graduate students in this field. Five of them have been authorised to award M.S. degrees to those having completed their studies. In May this year tutors involved in the training programs met in Guangzhou and formed a coordinating group. The whole undertaking seemed to be undergoing rapid development. Results were encouraging. Yet that was only the first gratifying step made and there is still a long way to go in the future.

Here we would like, on the basis of our own experience, to present our views as to how this undertaking is to be understood and considered.

Important Significance

With the progress of science and technology and with the development of higher education, the present-day world is giving increasing attention to the study of higher education. Many countries have set up research institutions, published specialised works and journals and held symposiums to this effect. This country is no exception: in order to satisfy the needs of the four modernizations and meet the challenge in the present technological revolution, we are pursuing a policy under which education is to face the modernization programs, the future and the world. The strategic philosophy in connection with the development of higher education is undergoing changes of historic significance. The fundamental objective of higher education should be the training of qualified personnel for the social and economic development of this country in the years to come. We must reform the present system and structure of higher education, bringing up to date the ideology, the contents and the methods of teaching as well as various regulations. It is, therefore, necessary not only to intensify the study of the general theories of higher education but also to carry the research work deep into the field of various academic subjects. It is through the training of specialised personnel in the field of College Physics Education that the research in higher education may be carried deep into the educational area of the academic subjects of physics. Such research undertaking entirely conforms to the needs of social development.

For a long time the broad masses of physics teachers have done a large amount of research work in the field of College Physics Education. In recent years, seminars on the teaching of physics have been held quite frequently. Many research findings have contributed positively to the improvement of teaching quality. Research work in this field is of great value and must be continued. Meanwhile we should not lose sight of the various limitations. Traditional research work tends to concentrate mostly on the teaching contents and center on the summing up of experience. How to bring the research work to a higher level is still a problem to be solved. With the advent of the age of information, the cycle for the renewel of knowledge becomes shorter and more frequent, and modern science and technology are widely used. This leads to changes in the concept of man's intelligence structure, thus making the development of higher education diversified and comprehensive and available to more and more people, whereby more options in the ways and means are available. All this poses a higher demand on College Physics Education. In order to solve the problems in connection with the reform carried out in the field of College Physics Education it is impossible to rely solely on the mastery of the teaching contents or the experience gained in the past. It is necessary to carry out systematic, comprehensive and predictive researches under the guidance of modern educational theories as well as other scientific theories. These researches may concern such academic branches as the physical science, the educational science and the behavioral science as well as scientific methodology. The training of graduate students of College Physics Education consists in the training of professional research personnel that will suit the current needs, improve the competence of college physics teachers, thus raising the level of research in physics education. It may be expected that such undertaking will gradually usher in an entirely new phase of development for the research of College Physics Education.

Physics is one of the basic academic subjects that were evolved the earliest. The theories and methods that guide the study of physics have, therefore, become the essential ground-work for various academic subjects. The philosophy of physics has often become an inexhuastible source of enlightment for other academic subjects in the development of new ideas. In higher education the study of physics becomes compulsory for many other specialised studies. The purpose of offering physics as an academic subject consists not only in imparting knowledge but also in training the students in the physical way of thinking so that they may apply it to the understanding and transformation of the world. This special feature of physical science constitutes an especially high demand on the College Physics Education. Seen from this angle, the training of graduate students in the field of College Physics Education and the successful carrying out of research and reform in College Physics Education are of special significance.

The Training Program

The training program of graduate students in the field of College Physics Education mainly involves three aspects: its objective, its research goal and the offering of academic courses. Our views on these three aspects have not yet reached sophistication. They remain to be constantly explored and summed up in the course of practice. We put forward our views just to subject them to further discussion.

Concerning the Training Objective

In accordance with the characteristic features of the physical science and the real needs it is beyond doubt that the graduate students of College Physics Education should first of all be trained in the ability to do research work in their special field of interest. As a result of the training received, they should have a better idea of the present state of affairs and the problems that remain to be solved, be able to choose research theses on their own and work on them. To achieve this, they should have a solid command of the basic knowledge of their own field, a rigorous attitude towards their studies and a daring spirit of exploration.

However. the study of College Physics Education is not a study of college education in general. but a study of a specific academic branch. It is closely connected with the teaching of physics in colleges and universities. After completing their studies, the graduate students of College Physics Education will in most cases undertake to teach at institutions of higher learning. (As a matter of fact seven of the eight graduate students have been assigned to teach at colleges or universities.) Before being admitted as graduate students, quite a few of them have just completed their college education. They lack teaching experience and their basic knowledge is limited. It is, therefore, important to give special attention to improving their competence in teaching college physics. It might be inconceivable for a graduate student to do research work successfully in the field of College Physics Education if he has very little knowledge of the laws governing the teaching of physics at colleges or universities or if he is not well-qualified as a physics teacher. On completing his (or her) studies a graduate student should be able to take up the teaching of various academic subjects in the field of physics apart from lecturing on College Physics Education courses.

Graduate students should also have good qualities both in moral character and in physical health.

To sum up, the objective of training graduate students of College physics Education should be the all-round development in morality, intelligence and physical health coupled with the competence to undertake the teaching of fundamental academic subjects of physics in general, and the courses in their major field of studies in particular, as well as the ability to do research work in College Physics Education.

Concerning the Research Goal

Graduate students may focus their studies on a certain aspect within the framework of the College Physics Education, yet it is inadvisable to narrow their scope of studies. Their actual research goal should be determined in relevance to the present state of College Physics Education and the needs of the educational reform and should be subject to changes with its development.

Listed below are some of the representative research goals that are currently available: the Teaching of General Physics, the Teaching of Experimental Physics and the Design of Laboratory Work, Modern Physics Education, the History of Physical Science and the Teaching of Physics, Modern Ways and Means in Physics Teaching, the Application of Micro-Computers in the Teaching of College Physics, the Measurement and Evaluation in Physics Teaching, Theories Guiding the Physics Education, Theories Guiding the Teaching of Physics, and the Educational Reform in Universities of Science and Technology. Of great significance are these research goals which cover the philosophy, the contents, the methodology as well as the ways and means of teaching. Further exploration should be made in these research goals in the future so that a new horizon of research goals may be developed. We should not and don't have to impose uniformity on the research goals. If people embark on different research projects in various aspects, this will only benefit the development of the cause of College Physics Education.

Concerning the Offering of Academic Courses

With different research goals in the field of College Physics Education, the courses offered should be different. However, the special features of a specific field of studies and the identity of the training objectives make it possible to put forth common requirements and assumptions.

Among the basic required courses should be courses of advanced natu and courses of theoretical studies in higher education. The offering of advanced physics courses has as its aim the laying of a solid foundation in the basic knowledge for the graduate students, which is necessary for the improvement of competence as college physics teachers. Courses of advanced nature include such theoretical courses as higher quantum mechanics, modern physics theory and others, and advanced courses relevant to laboratory work, such as laboratory work in modern physics, ways and means in physics laboratory work and others. The offering of theoretical courses in the field of higher education results from the special features of this specialty. In recent years there have appeared new branches of study, such as the Study of Higher Education, Psychology of Higher Education, Teaching Methodology in Colleges and Universities, all of which may be available as optional courses. Yet worthy of attention is the fact that graduate students should focus their studies on the problems of College Physics Education with the guidance of educational theories. Instead of overemphasizing the systematic nature of their studies, they should give special attention to the feasible nature of the theoretical courses while pursuing their studies.

The difference in the research goals results in the wide difference in the courses offered. Relevant specialised courses remain to be further developed. Research theses offered in recent years in connection with the teaching of physics in universities are worthy of further exploration. In addition, if such a course as 'On the Teaching of Physics in Universities' can be offered, it might suit the needs of most graduate students.

In the course of their studies arrangements should be made for the graduate students to participate for a certain period of time in the actual teaching. A year or a year and a half should be devoted to the writing of the degree paper.

Prospect for Development

Since the training of graduate students in College Physics Education conforms to the objective needs and is an undertaking of considerable significance, it is naturally a pursuit of promising prospect. As a matter of fact the College Physics Education research is not identical to the theory of teaching or the teaching methodology research in the traditional educational science. It has the College Physics Education as its object of research. It has its own specific contents and methods of research. With its own system of theories established it may develop into a new academic subject. Now everything is still in its initial stage. The College Physics Education has not yet formed itself into an academic course. The training of graduate students in this field, therefore, cannot be perfect. As the first step has been made, the next step will be followed. So long as we persist in our efforts, the training of graduate students in College Physics Education will be developed from lack of experience ot the gradual accumulation of experience, from imperfection to perfection and will in time win more understanding, concern, and support from the public. At present the urgent task in this country is to explore, to consolidate and to develop the practice of training of graduate students for master degrees. In future, when proper conditions present themselves the training of Ph.D's will be carried out in some schools.

The training of graduate students in College Physics Education may promote the development of research in that field and the successful research in the field of College Physics Education may, in turn, raise the academic standards of graduate students in that field. To elaborate in concrete terms, we have recruited graduate students in the field of College Physics Education, it is a matter of first importance at present to guarantee the quality of training as well as the academic level of the research papers to be written. That would mean doing a methiculous job of the research work, especially raising its academic standards thus paving the way for the formation of the College Physics Education as a new academic course. In reality this is another new undertaking which requires great creativity. The degree of difficulty in the work can never be overestimated. The major difficulty lies in the limitations of the knowledge structure of those (mainly college teachers of physics) who are involved in the project. They cannot easily adapt themselves to the situation in which various subjects are interwoven and mutually infiltrated, and rid themselves of the bondage of the old traditional ideas.

The process of overcoming these difficulties might be slow and tortuous, yet it is steadily on the move forward.

To achieve a steady development of training graduate students in College Physics Education, the tutors should first of all take the lead in making arduous efforts. In order to do a good job of training graduate students in College Physics Education it is quite necessary that there be a constant exchange of views and experience and that great efforts be made to encourage the co-operation among the tutors. And we also hope that there will be more exchanges on an international scale.

Light, Lasers and Holograms in
Physics Education

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A brief review of the properties of light which leads to the theory of the laser is presented. Various types of lasers, especially the helium-neon laser followed by its applications in physics laboratories are discussed. The subject of holography i physics education is treated in detail including the various typ of holograms and their applications. Finally the author's innovative course based on this new technology tailored to suit the needs of non-science majors attracted to the qualiative aspects of physics education is given.

Introduction

What is light? Light is what you see! Light is energy - energy on the move. Energy on the move is radiation. Energy the ability to do work. Light can do work. Sunlight, for example, works to help plants live and grow.

How fast does light travel? Galileo Galilei (1564-1642) designed a clever experiment to measure the speed of light; bu it failed. It was not until 1676 that the Danish astronomer O Roemer (1644-1720) showed that light is not instantaneous, although its speed is fantastically high. By timing the eclip of Jupiter's moons Roemer measured the time it took light to travel across the earth's orbit and calculated the speed of light. One of the first efforts to shed some light on ligh w made by the 17th century scientific genius Isaac Newton (1642-1727). His great book 'Optiks' was published in 1704. It lai the foundation for our modern understanding of light.

In 1666, at the age of 24, Newton demonstrated that white light is really made up of 7 colors - the colors of the rainbow. This band of colors Newton called the spectrum. Newton's theory of light, called the corpuscular theory of light, says that light travels in straight lines. Phenomena such as reflection and refraction can be explaned by Newton's theory, but it fails to explain phenomena such as interference and diffraction. The Dutch scientist Christian Huygens (1629-1695) 10 years after Newton's theory was announced, proposed that light is a form of wave motion. Huygens' principle involves that light travels in the form of waves. Nearly 100 years later, Augustin Fresnel (1788-1827) showed that light ca be diffracted provided that the obstacle and the wavelength of light are of comparable size. In 1801, Thomas Young (1773-1829) for the first time demonstrated the interference between two light waves and thus confirmed Huygenss theory. In 1820, the Danish physicist and chemist Hans Christian Oersted (1777-1851) showed that an electric current deflected a magnetic compass needle, thereby establishing a connection between electricity and magnetism. In 1831, Michael Faraday (1791-1867) showed that a changing magnetic field produced an electric current. The connection between electricity and magnetism is well documented in the well-known Treatise on Electricity and Magnetism by James Clerk Maxwell (1831-1879) i 1873. Maxwell predicted the existence of electromagnetic waves, traveling at a speed c = 186,000 miles/sec. Surprising enough, this was the measured speed of light. Light is a form of electromagnetic radiation. The existence of electromagneti waves was first demonstrated by Heinrich Hertz (1857-1894) in 1888. In 1895, Wilhelm Roentgen (1845-1923) discovered anothe form of electromagnetic radiation - X rays. In order to explain black body radiation, in 1900 Max Planck (1858-1947) postulated the quantum theory of radiation. He was awarded the Nobel Prize in 1918. In 1905, Albert Einstein (1879-1955) explained the theory of photoelectric effect, where a light quantum is called a photon. He was awarded the Nobel prize in

1921. The electron was discovered by J.J. Thomson (1856-1940) in 1897, who also proposed the first model for the atom. E. Rutherford (1871-1937) in 1911, proposed a different atom model in which the positive charge of the atom was concentrated in the center which he called the nucleus. In 1913 the Danish physicist Niels Bohr (1885-1962) provided a basic explanation for the way that radiation and matter interact. His work paved the way for understanding how atoms produce photons and how the quantum theory explains the nature of light. Bohr received the Nobel Prize in 1922. Today most of the observed phenomena associated with light radiations are explained with the help of quantum mechanics, a new view of how the physical universe works. Men such as Louis de Broglie, Werner Heisenberg and Erwin Schrodinger built the foundations of quantum mechanic In 1916 Einstein published his general theory of relativity which tied together much of this new understanding of nature. Very simply, quantum mechanics and general relativity pointed out that matter and energy are one and the same thing. Einstein's famous equation $E=mc^2$ shows this relationship. Charles H. Townes in 1951 working on radars came up with the idea of a MASER. In Russia, at the Lebedev Institute of Physics, A.M. Prokhorov and N.G. Basov were also working in the same area. In 1916, Einstein predicted that the existence of equilibrium between matter and electromagnetic radiation required that besides emission and absorption, there must be a third process, now called stimulated emission. This prediction attracted little attention until 1954 when Townes and cowarkers developed the first MASER using ammonia (NH_3). The idea of producing a LASER was first published in 1958(1) by Charles Townes and Arthur Schawlow and it was realized in operational form by T.H. Maiman in 1960(2). This how the world's first LASER was born (Ruby Laser).

LASER

The first gas laser (Helium-Neon) was built in 1961 by Javan, Bennett and Herriott(3) at Bell Telephone Laboratories in the U.S.A. The wavelength of this radiation is 11,500 Å, which is in the infrared. The commonly used He-Ne laser (λ =6328 Å) was first built in 1962 by White and Rigden also at Bell Laboratories. Today we have a number of lasers, in all three forms: solid, liquid and gas. The ruby laser is an example of a pulsed laser whereas the Ne-Ne laser is a continuous wave (CW) laser. In principle, the laser is a device that produces an intense, concentrated and highly parallel beam of light. As an example, a laser beam which is 1 foot in diameter, when aimed at the moon, will not be more than a mile in width.

Conditions for Laser Action

Two conditions must be fulfilled for laser action.

1. Population inversion.
2. Photon amplification.

When an atom is in an excited state, after a short time (10^{-8} seconds) without any external stimulus, it will make a transition to the ground state giving off a photon of energy $h\nu$ This process is called spontaneous emission. If a photon of energy $h\nu$ falls on the atom while it is still in the excited state, the atom is stimulated to make its transition to the ground state and gives off a photon of energy $h\nu$ which is additional to the one which triggered its emission. This process is called stimulated emission. The radiation produced by stimulated emission is in phase with the radiation which stimulated it.

Types of Lasers

Solid-state lasers. In this type, the active medium is a crystal or a piece of glass, often in the form of a rod. Ruby laser is an example of this type. Laser light comes from the chromium atoms embedded in an aluminum oxide crystal. The principal wavelength for ruby laser light is 6934 Å (693.4 nm). Other solid-state lasers include Nd:YAG (neodymium:yttrium-aluminum-garnet), important for sending signals along optical fibers at a wavelength of 1.06 μm. Molecular lasers, particularly those using carbon dioxide (CO_2) are among the most powerful and efficient, CO_2 lasers have operated in a continuous mode at a power of more than 200 kW. ($\lambda = 10.6\ \mu m$). Because of their high power, CO_2 lasers are used in numerous military, surgical and industrial operations.

Metal-vapor lasers use a mixture of gas such as helium and vaporized metal such as cadmium. The principal wavelengths for HeCd are 325.0 and 441.6 nm. Energy from an electrical dischar (an electric current flowing between two electrodes placed in t gas vessel) excites the gas atoms which then transfer energy through collisions to the metal-vapor atoms.

Semiconductor lasers. In this type, (GaAs) electrons falling from the conduction band back to the valence band by the application of an electric field, can participate in stimulated emission. Semiconductor lasers are relatively cheap, durable and efficient. Characteristic wavelengths (1.3 to 1.6 μm) coincide with the range of minimum energy loss in optical fibers, making such a laser useful for communications and audio-video read-out. Chemical lasers use the energy released in chemical reactions to pump a sample of atoms or molecules which can then undergo laser action. High energy outputs are possible, making them importnat in military applications. Dye lasers made from organic dyes are tunable over a wide range of wavelengths. Dyelasers can be used to distinguish closely spaced atomic or molecular states. This is used in areas such as photochemistry, isotope separation and detection of atmospheric constitutents. Free electron lasers are high-power tunable lasers in which a beam of high energy electrons passes through a spatially periodic magnetic field, causing the electrons' kinetic energy to be converted directly into light. One type of gas discharge lasers is the rare gas-halide type. An example is the XeF laser with transitions at 3510 and 3530 Å. XeF is an excimer, a molecule formed of an excited atom and a ground state atom.

Chemical lasers use the energy released in chemical reactions to pump a sample of atoms or molecules which can then undergo laser action. Besides these lasers, x-ray and gamma-ray lasers are being developed at the present time.

The Helium-Neon Laser(3)

Fig. 1 shows the energy level diagram. Pumping is accomplished by electrical excitation of helium atoms from their ground state to the 2^3S and 2^1S levels. The populations of these metastable states build up because there are no allowed transitions to lower levels. The 2^3S and 2^1S levels have very closely the same energy value as the 2s and 3s levels of neon. When a helium atom in the 2^3S or 2^1S state collides with a ground state neon atom, there is a high probability for the energy to be transferred to the latter (resonant energy transfer) raising it to a 2s or 3s state while the helium atom returns simultaneously to its ground state. Radiative transitions may then take place from the 2s and 3s levels (four each) to the 2p and 3p levels (ten each). Stimulated emission can speed up this process by laser action. Light waves emitted within the laser will occasionally be emitted parallel to the tube axis. Bouncing back and forth between the parallel end plates, these waves will stimulate emission of the same frequency from other excited neon atoms. The p levels may be less populated than the s levels because there is no direct transfer to them from a helium level. Whether an inversion will actually take place depends on the relative abundance of the He and Ne atoms in the mixture and on the electron temperature. The success of this scheme depends on the achievement of the correct ratios of excitation and decay rates, which are determined by the gas pressures, the power expended in the discharge, and the radius of the discharge tube which enters into the matter because of the collision of excited atoms with the walls. The optimum value of total pressure is about 1 torr, and the most favourable ratio of helim to neon is found to be 7 to 1. The optimal tube diameter seems to be around 6 to 8 mm. The tube length is about 100 cm. Details of descriptions of lasers can be found in the references 4, 5.

Properties of Laser Light

Laser light is monochromatic. The very process of stimulated emission depends on the fact that the energy of the photon causing the stimulated emission and that of the photon radiated in the emission process are the same. All the emergin light has a single wavelength or frequency. This feature is important in spectroscopy and other research areas where light a precise energy is required. Laser light is highly intense. The powerful nature of lasers is important when a lot of energy must be delivered to a tiny target during a short time interval as in laser fusion. The laser beam is highly directional. The beam is quite narrow and this is important for a number of applications, such as surveying, communications, the fabricatio of integrated circuits and laser fusion. Laser light is coherent. Coherence is of two kinds: spatial and temporal. Radiation is spatially coherent if successive waves are in phas (in step), and temporarily coherent if the wave trains all have the same wavelength and direction. Perhaps the most promising potential of lasers comes from time coherence. It is this property which permits the exploitation of radio and microwaves for communications. In fact one single laser beam has in principle more information-carrying capacity than all the radio and microwave frequencies in civilian and military use combined.

Applications and Techniques

Time coherence (monochromaticity) lies at the very basis o wireless communications system, and information-bearing capacity is proportional to the wave frequency. In theory, a single laser beam could carry some 10 million television broadcasts at once! It seems likely that when men first go to Mars, they will send live television transmissions back to Earth on laser beams. The red emission from the helium-neon laser has a frequency of 5 x 10^{14} hertz (that is 500 million megahertz or 500 terahertz). This is roughly one billion times greater than radio and 10 million times that of T.V.; it is more than 10,000 times the highest useful microwave frequencies. Since the channel width for telephone conversation is 4 kilohertz, the capacity of a single laser beam for telephone communication is, considering the world's population, beyond all our needs. The same is true for television where the 6 megahertz channel width divided into the 500 million megahertz frequency of the red He-Ne laser line shows the possibility of about 80 million T.V. channels. Since various kinds of information, such as telephone, radio, and computer data, can be transmitted on one carrier, if it is sufficiently broadband, the potential of lasers for communications is virtually limitless. Lasers are used in range finding, tunneling, measurement of small and large distances, drilling tiny holes in solids, and reading bar codes on items in supermarkets.

Q-switching is a method by which laser action is prevented from occurring until a thorough population inversion is attained

Mode-locking. The various laser modes in the active medium can be locked together into short pulses and made to be in phase by using a very thin modulating element made of a bleachable dye.

Non-linear optics. An optical device is nonlinear, if the optical output intensity is not linearly proportional to the optical input. This phenomenon can be used to achieve a number of nonlinear effects such as the production of harmonic waves, conjugate waves, and optical bistability. In harmonic generation or frequency doubling, for example, original infrared light can be converted to green light with an efficiency of about 80%. Lasers play an important role in experiments dealing with saturation spectroscopy, two-photon spectroscopy and Raman scattering. Details can be found in references(10).

Isotope separation. A mixed sample of isotopes in an atomic beam can be subjected to an intense laser beam that excites one isotope and not the others. Laser separation of isotopes can be more efficient, especially for the heavy elements that are used in generating nuclear power.

Laser fusion. Nuclear fusion is a reaction process in which two light nuclei, such as deuterium and tritium fuse together into a heavier nucleus helium, and in so doing release an enormous amount of energy. There is enough deuterium in the oceans to provide more than a million times more electrical power than the whole world uses today. The laser fusion projects use either a neodymium - YAG laser or a CO_2 laser. It is a cheap, reliable power, without pollution. When fully realized, it will be the most important contribution to man's well-being that any invention can make.

Military applications of lasers include infrared radar imaging of orbiting space objects, laser range finding, naval communications, tracking systems, automatic boresights and defense against missiles. Because of their high energies, CO_2 and gas-dynamic lasers are frequently used for military applications.

Lasers are also used for recording and playing audio/video disks. Integrated circuits consisting of small lasers, prisms, switches and filters can perhaps perform many of the functions now carried out with purely electronic integrated circuits. The high intensity and the well defined focus of lasers make them highly useful in a variety of medical problems. Laser beams can cut tissue with reduced bleeding and can vaporize large masses, such as tumors, without physical contact. Fiber optics plays an important role in many medical treatments. CO_2 lasers are used in the treatment of malignant tissues. In eye surgery the laser is used to weld the detached retina. Argon and neodymium - YAG lasers are used for coagulation of abnormal blood vessels in plastic surgery, dermatology and for the control of bleeding ulcers. Argon, ruby and dye lasers are used for the treatment of ocular diseases ranging from diabetic retinopathy to glaucoma. Other applications include the use of CO_2 lasers in gynecology, urology, use of ruby, argon and CO_2 lasers in opthalmic surgery, and the use of neodymium - YAG laser in the treatment for bleeding of the uterus.

Laser Safety

Laser radiation is particularly dangerous, mainly becaus its high spatical coherence (which means that it can be focuse down to very high power densities). Never look into the beam any laser. The greatest danger is the inadvertent direction an undiverged laser beam directly into the eye. Always be aw of the beam path and be aware of others when adjusting the pat Extreme caution must be used in any work involving any type o laser. Maxium permissible exposure levels and safety measure be employed can be found in "The ANSI Laser Safety Guide", American National Standards Institute, 1430 Broadway, New York NY 10018.

The Speckle Effect

Anyone observing a diverged laser beam against a diffuse surface will note a granular appearance. If one squints or moves back, the speckles become larger. No matter where one's eyes are focused, the speckles will appear sharp. Moving sideways causes the speckles to move too. Curiously enough, the speckels do not exist in the reflected pattern but are created in the eye itself. Laser light reflected from a diffuse surface will enter the eye,, producing bright speckles where random fluctuations cause constructive interference on the retina. Such interference maxima can be related to a local convergence, real or virtual, of laser light in the vicinity of the observed area, in the plane in which the eye is focusing. By moving the head sideways, the speckles will move in the same direction for the farsighted person, just as an object observed on the far side of an open window sill. Conversely a near-sighted person will see the speckles move in opposition. Correct vision will produce no apparant parallax.

HOLOGRAPHY

Images can be formed without the use of lenses by a proce known as holography. This method was first conceived by Denni Gabor in 1947 and he was awarded the Nobel prize in Physics in 1971 for his pioneering work. In ordinary photography, the fi records the amplitude or intensity of the reflect light from t object; whereas, in the case of a hologram, both the amplitude and phase of the wave are recorded. This is made possible by using a reference beam in addition to the object beam.

The image formed is the result of the construction of the wavefronts which would have reached the eye after an incident beam is scattered by points on the object. To form a hologram, the object is illuminated by a broad beam of monochromatic coherent light from a laser. Light scattered from the object strikes the photographic film. Every point on the film receives light from every point on the object. The film, when developed, is called a hologram. The resultant density at any point of the hologram depends on both the amplitudes and phases of all interfering wavefronts that reach that point. To view the picture later, the image is reconstructed by placing the hologram in a laser beam; both a real and a virtual image are formed in depth. When the viewer's eye is moved from side to side, the 'near' parts of the 3D scene are seen to move, relative to the more distant parts. It is even possible to make a hologram which will allow the viewer to move in a 360° path around the image, seeing all sides of the image in 3D. The theory of holography is mathematically complicated; but the essentials can be explained and understood from physical arguments.

If the hologram is cut into several pieces, each piece gives the same image as the entire hologram, (although with less sharpness) for it is only the relative changes in grating space along the hologram that give rise to images. The image can be enlarged simply by viewing the hologram in divergent light of wavelength longer than with which it was made. If coherent x-ray beam can ever be achieved, high resolution can be obtained and it will be possible to see (visually) biological or other structures much smaller than those it is now possible to see using visible light. Holography is being used in many areas of physics, chemistry, biology and engineering. It is also used as a medium in art. Details can be found in the references 4, 5, 6, 7.

Types of Holograms

Absorption holograms

The holographic information is coded in the emulsion according to the localized microscopic differences in the absorption of light. Such a hologram is referred to as an absorption hologram. If this hologram is put through ableachin process, the product is called a phase hologram. Phase hologra absorb less laser light and hence create brighter images. All holograms will become either absorption or phase type. For the different holograms, in the construction stage, the difference usually nothing more than the differing angle between the reference beam and the object beam as they interfere on the fil This angle difference can produce very pronounced differences among holograms in the reconstructed stage. When the angle between the reference beam and the object beam increases, the interference patterns are closer.

If Fig. 3, location I is known as the in line position and is the position of the holograms recorded by Gabor in 1948. Fo reconstruction, the reference beam must be sent through the hologram at the same angle relationship it had in construction. This is called a transmission hologram.

Location 2 is typical of hologram placement for off-axis hologram. Off-axis means that the reference beam and the object beam are not coming from the same direction. As long as the angle between the object beam and the reference beam is less than 90°, the hologram is called a plane hologram, meaning that the holographic information is contained in the two dimensional planes of the emulsion. As the angle of the reference wave increases to around 90°, as in position 3, the spacing between the exposing interference fringes becomes quite small. A hologram made in this fashion can be reconstructed with the beam incident on the hologram in a narrow range of angles about the original angle of incidence. (Bragg-effect hologram). AT 90°, the fringe spacing has become small enough to say that the recording is taking place throughout the volume of the emulsion. Hence such a hologram is called a volume hologram. When the photographic plate is exposed in position, the interference fringes are parallel or nearly parallel to the emulsion. The processed hologram will also act as an interference filter, filtering out all but a narrow band of colors. This is called a white light hologram because it can be reconstructed with white light. The hologram known as multiplex hologram is described under applications. We can also create computer-generated holograms. The object is specified mathematically and the computer calculates the location of interference fringes. These fringes can be plotted with an x-y plotter, and the resulting pattern photoreduced and illuminated with the assumed reference wave.

Dichormate holograms

The optical properties of holograms recorded in dichromated gelatin films are very close to ideal. When volume holograms are formed in dichromated gelatin, their diffraction efficiency can approach the theoretical limit of 100%. Either a transmission or a reflection hologram can be recorded in this material with both high diffraction efficiency and low noise. A step by step description of how to make a hologram can be found in reference 8.

Applications

1. Three dimensional display

The excitement and attractiveness of full-perspective, three dimensional displays have increased the use of holography in advertising business. Multiplex holography is an example. The procedure is to photograph the object on a standard 35 mm black and white film with a motion picture camera. The object is sitting on a rotating table and about 1080 individual frames are exposed as the table makes a complete rotation. Each separate 35 mm frame is then illuminated by a laser source and projected through a cylindrical lens on to a marked strip of film simultaneously with a shaped reference beam from the same laser making a strip hologram of the projected image. The process is repeated for each frame as the holographic film is moved to expose another strip. The result is a stereographic hologram that can be reconstructed by a vertical filament white light source. The illusion of three dimensions results from the face that each eye sees the object from an offset parallax.

2. Holographic interferometry

This is a technique for measuring small displacements. It can be used to observe and analyze, for example, the strain in a fractured bolt, the shock wave from a bullet or hidden flaws in aircraft tire. Another form known as double-exposure holographic interferometry has found widespread application in several cases of non-destructive testing.

3. Holographic Optical Elements

Conventional optical elements such as gratings and lenses can be replaced by their holographic counterparts. These are often used in optical data processing systems.

4. Holographic Optical Memories

Lasers and holograms are starting a major revolution in th size, capacity, speed and usefulness of computers. A hologram used as an information storage tool. Holographic memories are used in modern computers.

I have tried to summarize the basic theory and properties of lasers from a non-mathematical point of view. I have then brought out the various applications of the laser including holography. This fascinating subject has attracted a number of scientists as well as artists. As the laser and its applications revitalized the subject of optics, many physics departments utilized this opportunity to introduce courses that will attract the non-science majors. I have introduced such a course, "Light, Lasers, and the Visual Image", a few years ago here at Long Beach and the details of the course can be seen in reference 9. It has turned out to be an ideal course in Physics education and we strongly urge you, if time permits, to introduce such elective courses for non-science majors. Perhaps, among other things, such a course may make the students accept science as a part and parcel of their world and one with which they can cope and to some degree appreciate and understand.

CONCLUSION

Lasers are being built and sold and put to work in factories, hospitals, schools and research laboratories. Lasers may someday help to defend us against missile attack and might even make the golden dream of controlled hydrogen fusion power a reality. Lasers may help cure certain types of cancer, and they will probably go with the men who fly to Mars.

All of this has happened because an army of men, over the past 3 centuries or so have asked themselves, "What is light?" We still don't have a complete answer; but we have all had a lot of excitement trying to find it.

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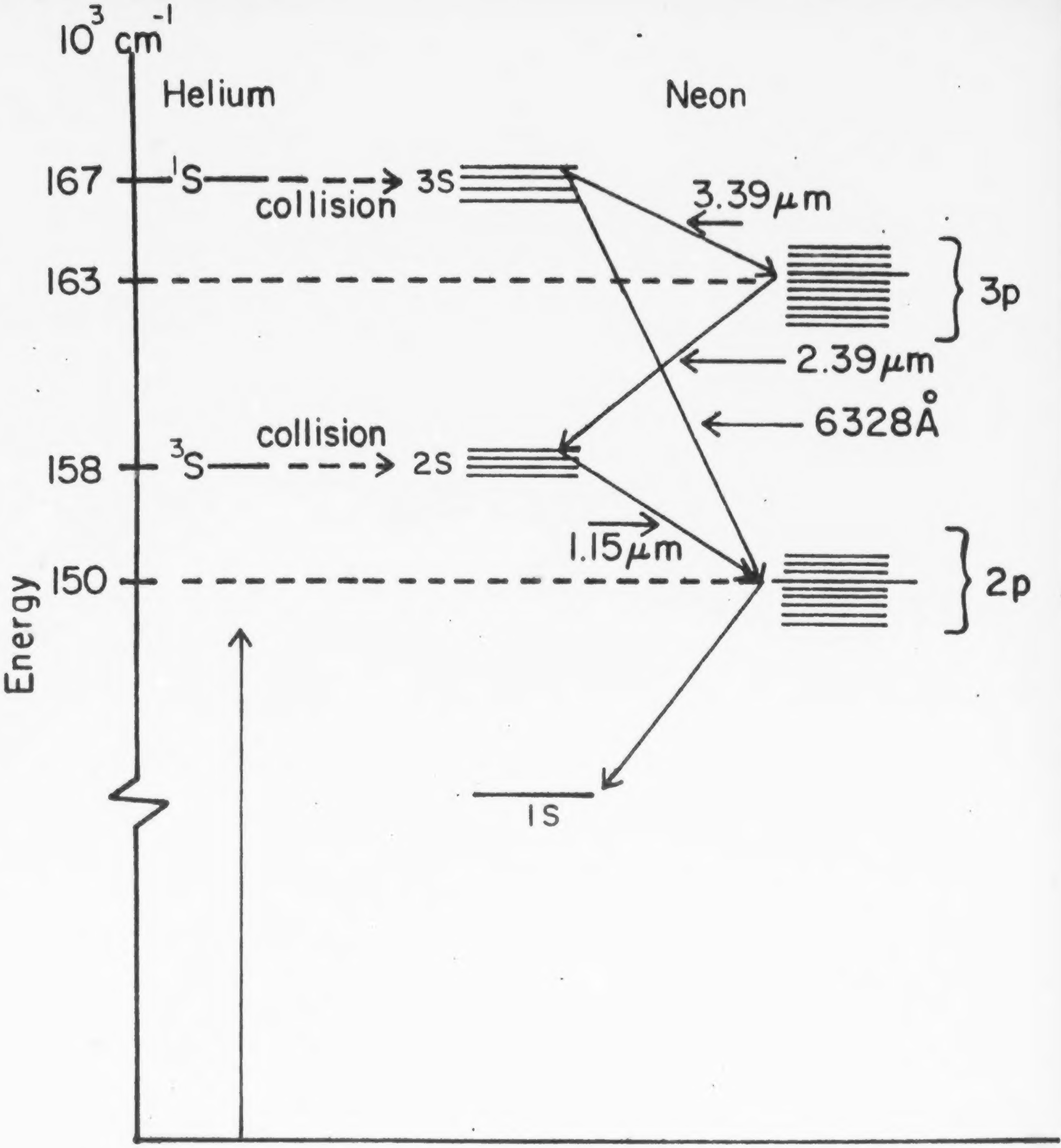

10^3 cm^{-1}
Helium
Neon
167
^{1}S
collision
3S
3.39μm
163
3p
2.39μm
6328Å
collision
158
^{3}S
2S
1.15μm
150
2p
Energy
1S

Figure I. Energy levels of helium and neon involved in laser action.

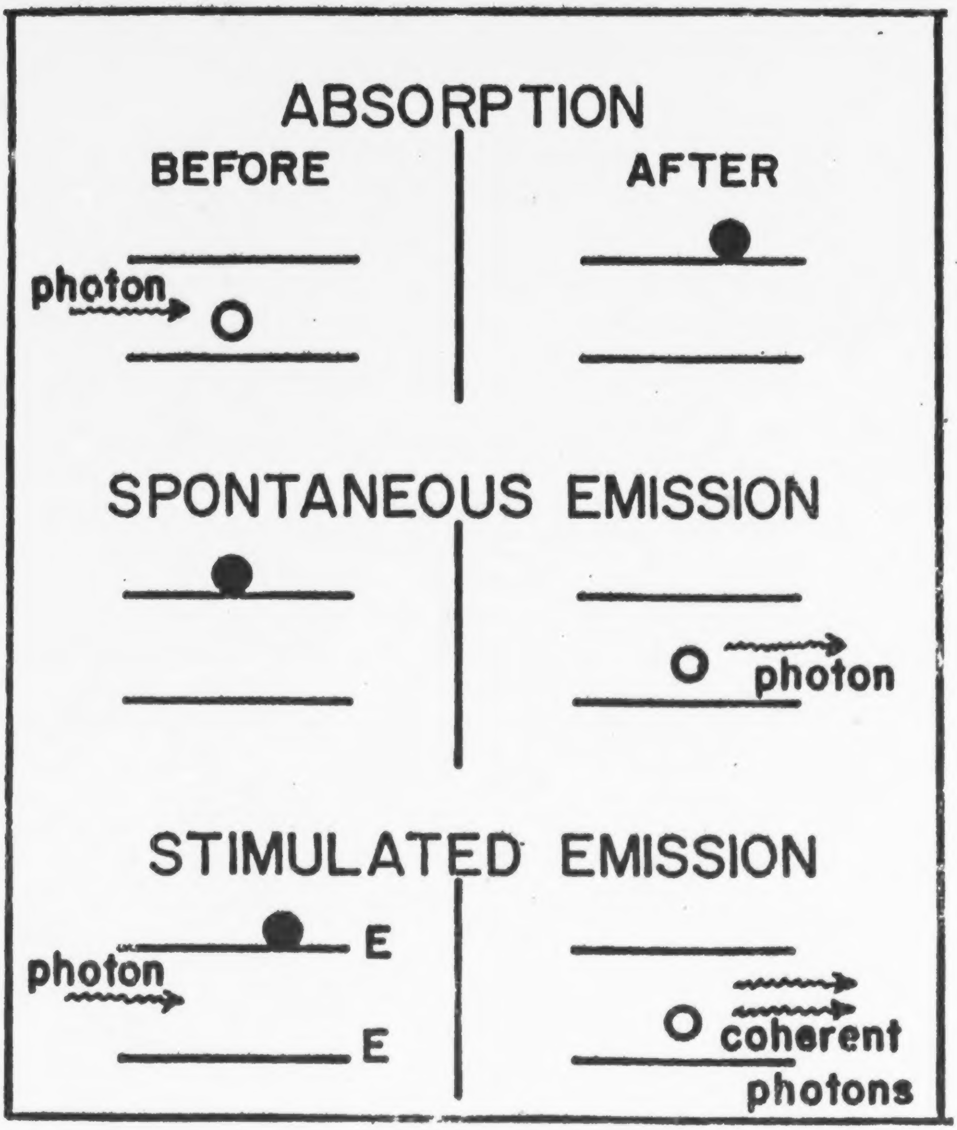
ABSORPTION
BEFORE
AFTER
photon
SPONTANEOUS EMISSION
photon
STIMULATED EMISSION
E
photon
E
coherent
photons

Fig. 2. Energy state transition diagram differentiating among absorption, spontaneous emission and stimulated emission.

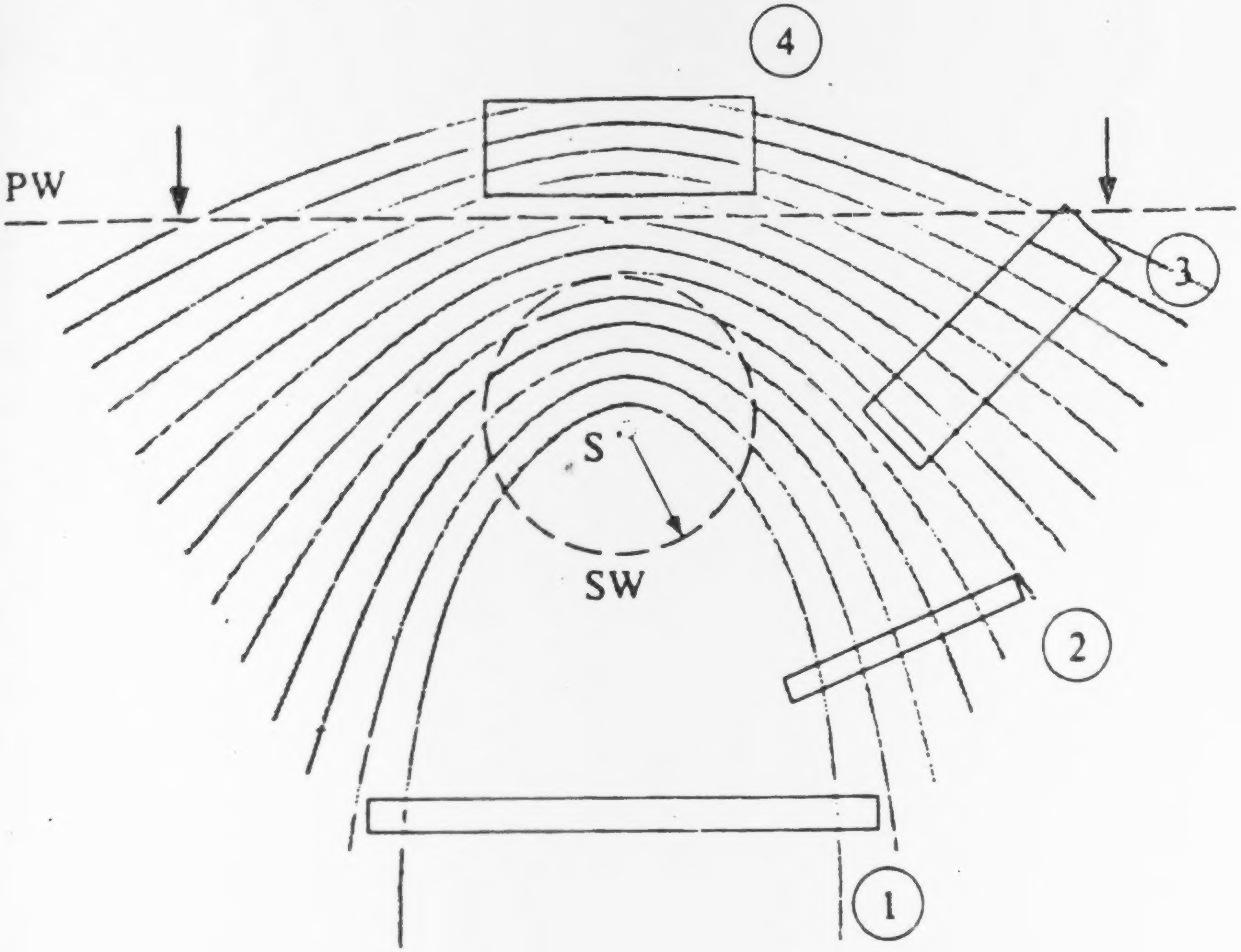

Fig. 3 - Interfering plane wave(PW) and spherical wave (SW), represented by dashed lines. Light lines show loci of interference maxima. (Drawing taken from reference 5.)

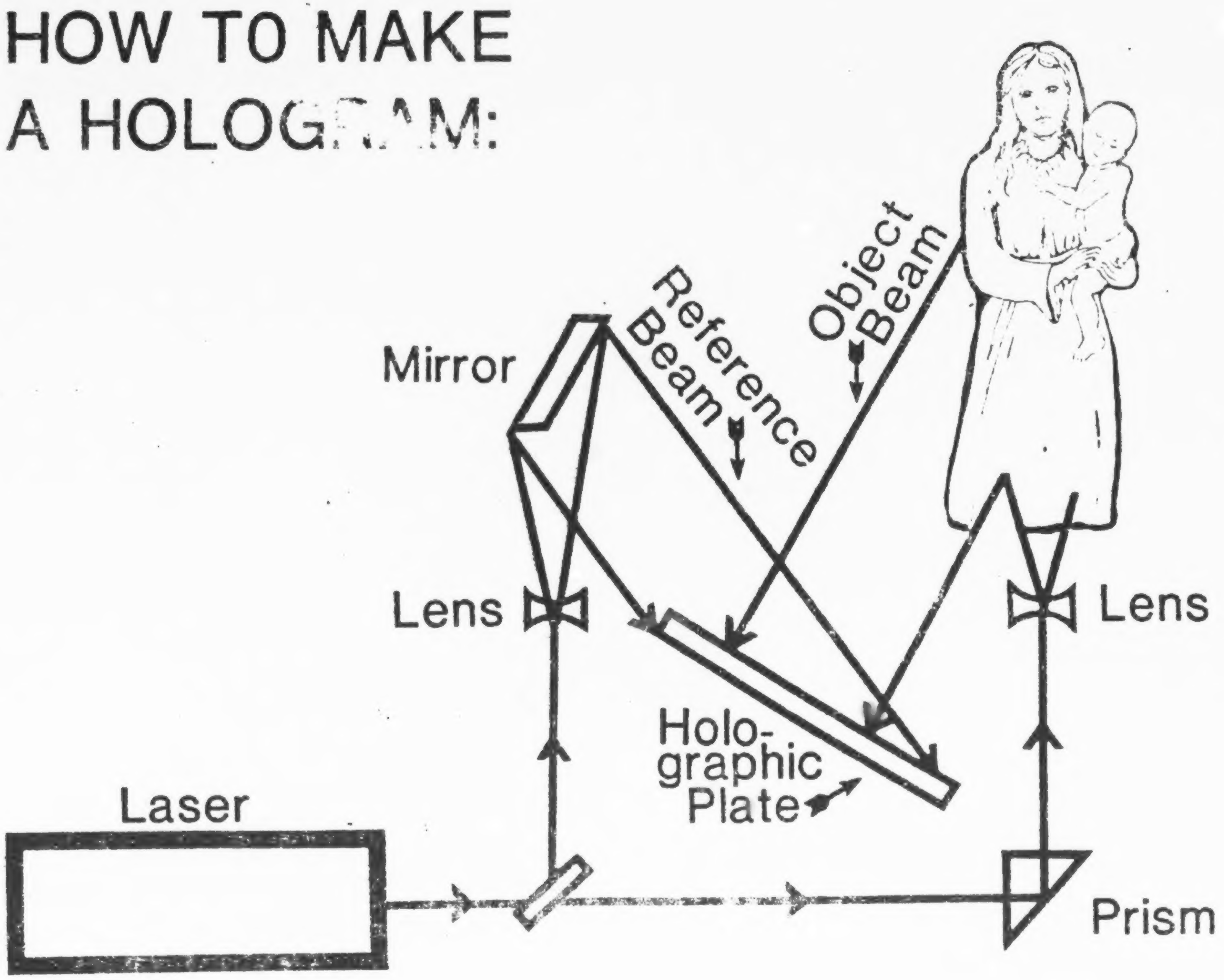
HOW TO MAKE
A HOLOGRAM:
Mirror
Reference Beam
Object Beam
Lens
Lens
Holographic Plate
Laser
Prism

Fig. 4. How to make a hologram.

Multifunction apparatus for Franck-Hertz experiment

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I. Introduction

The Franck-Hertz experiment is one of the essential experiments in the present modern (medium) physics laboratory experiment teaching program of colleges of science and technology of our country. At present, so far as we know, there are three types of such apparatus used for this experiment. They are developed by Nanjing Institute of Technology, China University of Science and Technology and our University respectively. In the two types made by the other two schools mercury is used, while inert gas (neon or argon) is used in our apparatus which we have developed into a multifunction type for the Franck-Hertz experiment.

This experiment was first performed by Franck and Hertz with mercury discharge tube in 1914. This experiment proved the theory of Bohr's atomic structure and showed that the atomic energy levels are discontinuous. It is of great help to the understanding of atomic structure and the development of modern physics and became one of the most famous physics experiments. It was just because of this that Franck and Hertz received the Nobel Price of physics in 1925.

The energy needed by exciting mercury atom from ground state to the first excited state is low, merely 4.9ev, the accelerating voltage can be obtained with ordinary battery. Usually the experiment is done with a triode filled with mercury vapor. Later improvement of the tube structure (changing triode to tetrode) gave us better results. Mercury is a liquid at room temperature and becomes vapor when heated, but the temperature has a great influence on the pressure of mercury vapor. For this reason, it is necessary to keep the temperatury of the tube constant, otherwise the results of the experiment will vary with the temperature. But this problem will not exist for neon or argon because neon or argon is a gas at normal temperature, and the heating is not needed. So the problem of temperature change does not exist.

II. Function of the Apparatus of our Design

(1) Measurement of the First Excitation Potential

We began the research in 1979. In 1980 we completed the apparatus [1] . Many users hold that the property of the apparatus remains stable and the results are satisfactory. Fig. 1 shows the result of experiment with neon gas tube. We can demonstrate this experiment in class by using a slow-scanning oscilloscope. The phenomena observed are quite clear.

(2) Light-ring method for the Franck-Hertz experiment

Having observed and disscussed the light rings appearing in the experiment with neon gas, we had found out the relationship between the number of the light rings and accelerating voltage and between light ring spectra and neon atomic energy level, thus obtaining a new method for the Franck-Hertz experiment [2] . The colour of light ring is tangerine. Light rings appear or vanish at special accelerating voltages and are not continuous. It follows that atomic energy levels are discontinuous. Light rings of neon atoms only appear at their excitation potential. The number of light rings corresponds with peak values of the tube current one to one. The region where

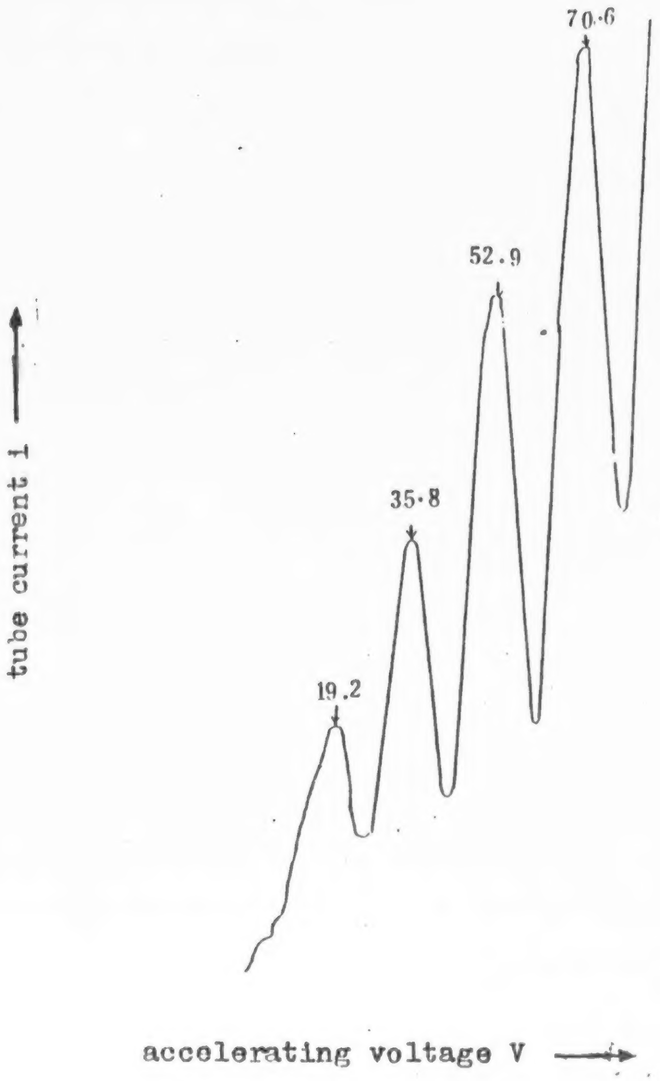

Fig.1 Result of experiment with neon gas tube

light rings appear is the place where the free electrons exchange their energy with atoms. The difference of accelerating voltages between two neighbouring rings is equal to the atomic excitation potential. The observation and description of light rings therefore is another way for the Franck-Hertz experiment. This way is so concrete and intuitive that students must get interested in this experiment. It is helpful to the understanding the essence of this experiment. Fig. 2 is a photograph of light rings taken under the accelerating voltage of 72 V and the presence of four peaks in the tube. From the photograph, we can witness four rings clearly. Fig. 3 shows the photoelectric record of those light rings in which the intensity of light ring is reduced to one half.

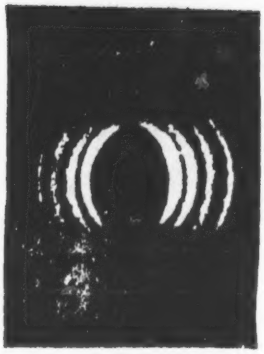

Fig. 2 Photograph of light rings

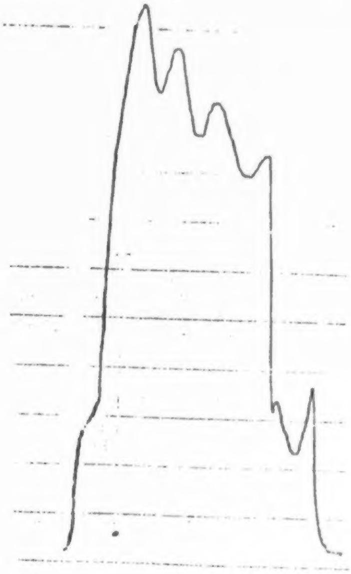

Fig. 3 Intensity of light rings by Photoelectric record

Under suitable conditions, a projector can be used to enlarge the images of light rings in class. It can be found that light rings appear (or vanish) one after another with the increase (or decrease) of accelerating voltage. This vivid phenomenon attracts the students attention to excite their wish for study of science.

(3) High energy level Franck-Hertz experiment

Performing the Franck-Hertz experiment with the light ring method, we know that the light ring is a manifestation of high energ level of neon atom. It shows that when an electron collides with an atom, and if the energy of the electron is higher than the first excitation potential and is equal to the second (or still higher) excitation potential of the atom, the atom would be excited to a high energy level directly. But when the energy of electron is higher than the first excitation potential, the collisions between eletrons and atoms may be elastic or inelastic. There exists an exciting probability in this case. The result of ordinary Franck-Hertz experiment indicates that collision between electrons and atoms usually excites the atoms mainly to the first excited state. Thus if you want to perform the experiment of high energy level, it is necessary to increase the excitation probability of high energy level and decrease that of first excited state. For increasing excitation probability of high energy level, you should create conditions for level-by-level excitation and increase the factor of such excitation and the inelastic collision of second kind, thus making the atoms transfer from metastable level to high energy level. Because level-by-level excitation not only permits the atom to be excited to a higher energy level, but also prolongs lifetime of the first excited state. In this way exciting probability of high energy level is increased, at the same time the probability of first excited state is decreased, and metastable atoms are essential to the level-by-level excitation. Thus enhancing inelastic collision of second kind is helpful for metastable atoms transfering to higher energy level,i.e. for increasing the exciting probability of high energy level. According to the above, we improved the circuit, acceleration region and impacting region. We seperated impacting region from accelerating region and limited the accelerating region within a small space, thereby reducing the chance for electrons to impact atoms, i.e. reducing the exciting probability of first excited state, enabling electrons to enter impacting region (due to obtaining energy higher than that of first excited state) and impact atoms in ground state to a higher energy level directly. On the other hand, extending the impacting region is helpful to the level-by-level excitation of the atoms, promoting metastable atoms to transfer, an the increase of excitation probability of high energy level. In this way we have performed the Franck-Hertz experiment of higher energy level[3]. Fig. 4 shows the result of this experiment. From the result,

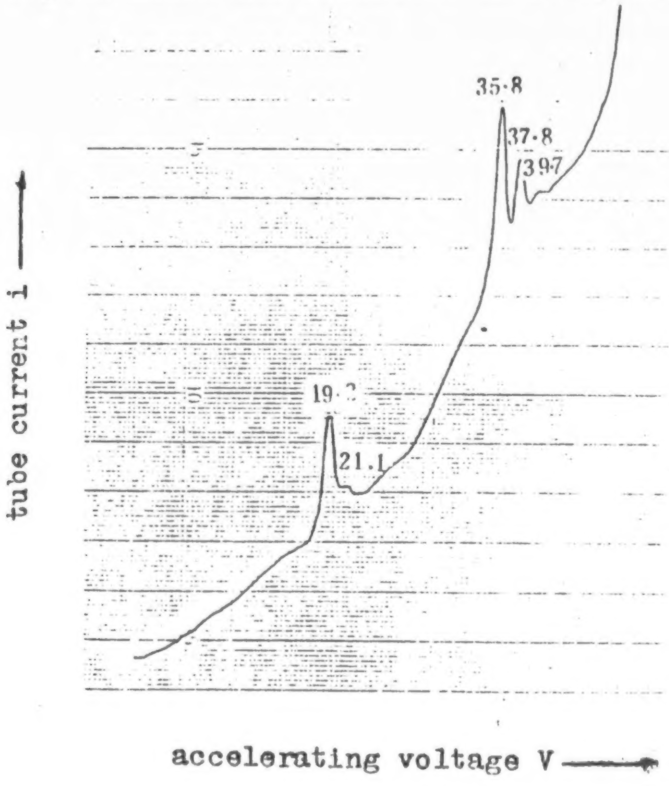

Fig. 4 Result of Franck-Hertz experiment of higher energy level

we obtain not only the first excited state ($2p^53s$), but higher state ($2p^53p$) and still higher excited state ($2p^54s$, $2p^54p$, etc.). The experiment result agrees with theoretical value [4].

In brief, we improved our original apparatus to obtain such a manyfunction apparatus (or multilevel apparatus) for Franck-Hertz experiment. In this new apparatus, the circuit is changed to use integrated blocks to include a voltage-stabilizing circuit, an operational amplifier and a scanning circuit. The accelerating voltage is changed to show digits. Two kinds of tube (high energy level tube and low energy level tube) are fixed in this apparatus, so that two kinds of Franck-Hertz experiment can be performed with a single apparatus.

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OPTICAL PUMPING ECHO

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INTRODUCTION

The transient method and Fast Fourier Tranformation in NMR technique have been the foundation of modern spectroscopy. Since the appearance of spin echo, relaxation times acurate measurement, sensitivity enhancement, 2-dimension spectroscopy etc were developed sucessfully. In the case of spin echo, a rf magnetic field with great magnitude and short interval was employed to excite the sample. Usually a pulse sequence is used. The rf magnetic field frequency f has to satisfy the resonance condition:

$$f = g \beta H/h$$

where H is the resultant magnetic field, g is the splitting factor, β is the nuclear magneton and h is the Plank constant. When the first burst (pulse) of radiation is applied for a time $t_{\pi/2} = \pi/2\gamma H_1$, H_1 is the magnitude of the rf field, γ is the "gyromagnetic ratio", the nuclear spin magnetization will tilt over $\pi/2$ degree, and start to precess and fan out and produce a decreasing signal which is referred to as a free induction decay. The free induction decay signal eventually reaches zero. But if during the fanning out process, a π pulse is applied at a time τ, the decay is then revers, and at time 2τ, an echo is produced. [1]

In video frequency region people established a similarity between the response of a two-level dipolar system to that of a magnetic spin in a dc magnetic field. This point of view makes it possible to visualize the atomic dipolar behavior in terms of the conceptually simple spin procession. That is to say the atom systems are shown to be identical to those of gyroscope in the magnetic field. The visualization is very useful in practical experiment design. [2]

The excitation of atomic dipole in video frequency employs a more powerful and shorter pulse sequence of light source (lsser). It need more sensitive and special device to detect the echo signal. Technically it is very difficult and lacks information as well. This remarkable effect has made rather slow progress in contrast to the spin echo system studies. [3, 4]

Early in the seventies, a scientist advanced a method which applied a $\pi/2 - \tau - \pi$ Stark pulse sequnce in $C^{13}H_3F$ and NH_2D. In this experiment the optical radiation was cw, while an electric field was used to switch the molecular in and out the Stark splitting level. The echo had been observed. It was a great advancement. [5]

In the present work, the $\pi/2 - \tau - \pi$ pulse sequence is a few Gauss of magnetic field which rapidly alters its direction to excite the sample.

What we got was an optical echo signal, modulated with hyperfine Zeeman splitting frequency containing both optical and magnetic resonance characteristics (sensitive and accurate) and useful informations as well.

The method can easily develop optical pumping technique operating in the transient way. It is reasonable and offer a good prospect.

APPARATUS CONSTRUCTION

Fig. 1. shows the diagram of apparatus.

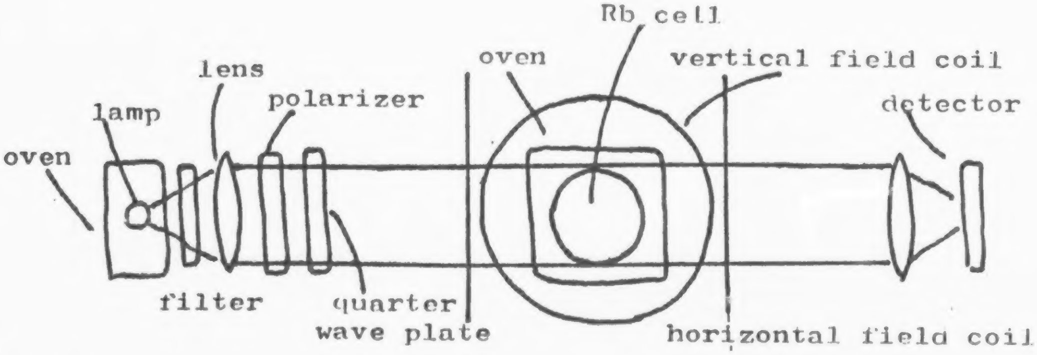

Fig. 1. Equipment (top view)

A rubidium lamp lighted with a rf (60 MC) oscillater, warmed up to 90 c automatically by an oven.

The lens system collimates the light from the source. The interference filler removes all radiation but D_1 at 7950 Å which is circularly polarized by a polarizer and a quarter wave plate.

A sample cell containning two stable isotopes Rb^{87} and Rb^{85} and warming up by an adjustable temperature control oven is irradiated with resonance light.

Two sets of Helmhotz coil are placed in vertical and horizontal position.

A signal detector is built with silicon photocell followed by a pre-amplifier and connected to the scope.

EXPERIMENT PROCEDURE AND RESULT

Stable rubidium exists in two isotope form Rb^{87} $(I=3/2)$ and Rb^{85} $(I=5/2)$. Our discussion is limited to $I=3/2$ isotope, the other one can be explained in a similar way.

The energy diagram for the ground state and the first excited state of Rb^{87} is shown in Fig. 2. When the Rb atoms are subjected to a magnetic field (pre-polarized) and D_1 resonance radiation; if the photon of D_1 conveys positive angular momentum, after a time equal to a few relaxation times, the atoms will collect in the $m_F = 2$ ground state. The process is called optical pumping and forming a magnetization along external magnetic field.

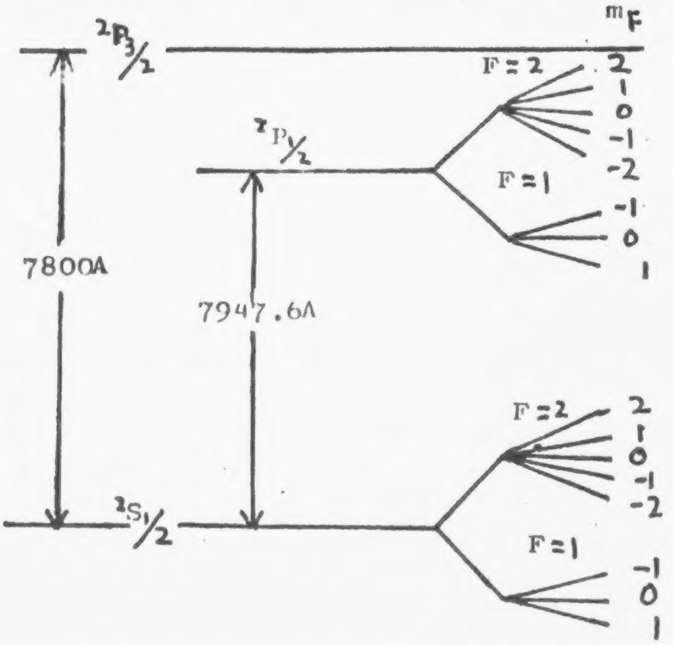

Fig. 2. A diagram of the energy levels of Rubidium 87 ($I=3/2$).

In the case of optical pumping, howerver the energy and the angular momentum of the photon are of importance. If a positive angular momentum photon is absorbed by the sample, the quantum number m_F must increase by 1. and transition happens. Eventualy the atoms in all the ground state sublevel can absorb the photon except the atom in the $m_F = 2$ state; since there is no $m_F = 3$ state in the 2p energy level. An atom in an excited state emits radiation spontaneously. Thus the atoms tend to return to all the ground state sublevels from the various excited state sublevels. Because of continual absorption and subsequent re-emission of the photons, the atom will collect in $m_F = 2$. The sample cell now becomes more transparent as a result of there being no more atom in ground state sublevels to absorb the radiation light. [6]

When the external magnetic field is then switched to a perpendicular direction in a time smaller than the precession period; the magnetization of the sample remains stationary and starts processing around the field. The Rb vapor sample changes from a condition of maximun transparency in the z direction to a maximun absorption and back again for each processing cycle. This alternation can be detected and observed on the scope. [7]

The oscilating signal changes in frequency f;

$$f = g \beta_0 H / h$$

where β_0 is the Bohr magnetion g_F is the Lande factor,

$$g_F = 1 + \frac{j(j+1)+s(s+1)-L(L+1)}{2j(j+1)} \quad \frac{F(F+1)+j(j+1)-I(I+1)}{2F(F+1)}$$

Since the magnetic field is perpendicular to the radiation light; the signal will be decreased exponentially with a relaxation time of a few mili-seconds. We switch the magnetic field during the process to the opposite direction at time τ; then the magnetization will be rebuilt and produces an optical echo at time 2τ. Fig. 3.

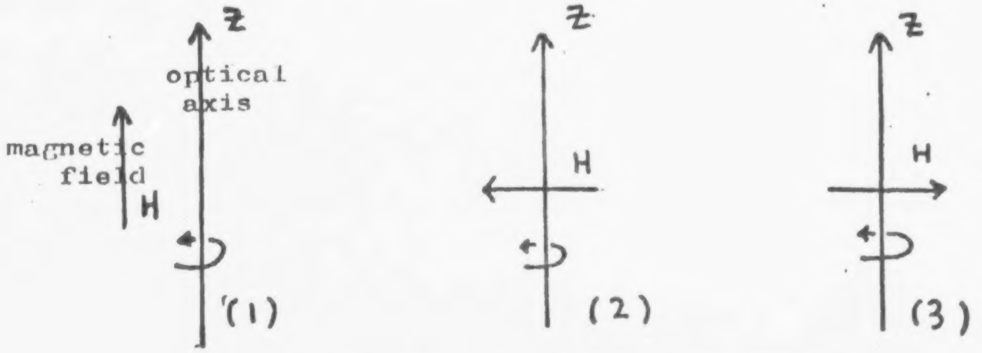

Fig. 3. Magnetic fields and radiations beam directions during:

(1) pre-polarization, (2) decay precession,
(3) echo forming.

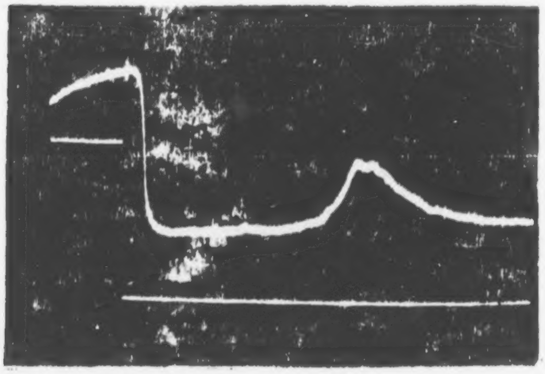

Fig. 4. Optical pumping echo (above) and pre-polarizing magnetic field (below).

Not: (Fig.4)

(a) The optical axis is set along the component of the horizontal earth magnetic field compensated with a fixed external magnetic field.

(b) When polarization has been achieved, switch off the external field and then the magnetization of the sample processes around vertical earth magnetic field ($H_\perp$).

(c) At the time τ an external magnetic field is subjected along the oppsite direction of H with twofold magnitude, an echo happens at time 2τ. Fig. 5.

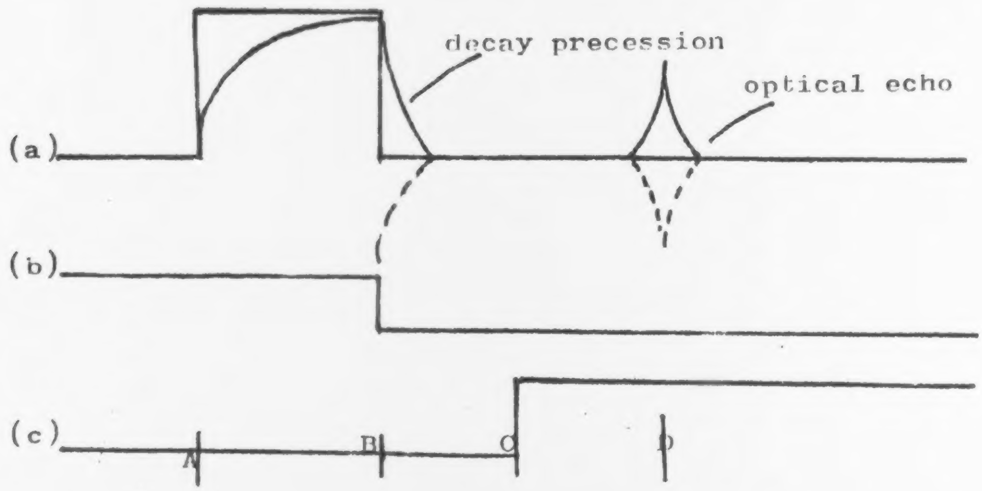

Fig. 5. Times reference in processes

AB: pre-polarization time

BC: decay precession (around H)

CD: magnetization establishing

SUGGESTION

(1) Echo groups by "Carr-Purcell" sequence. Fig. 6.

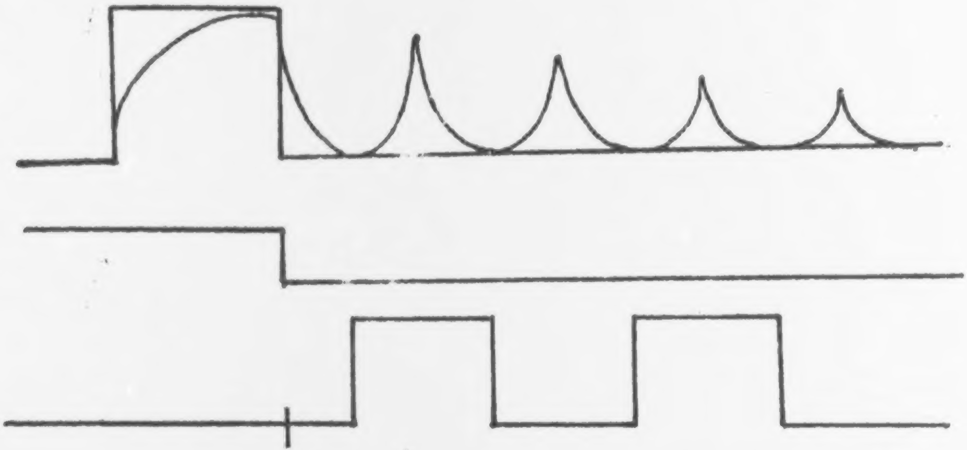

Fig. 6. The times interval and magnetic field directions in the "Carr-Purcell" pulse sequence.

With the peaks of the echos try to measure the relazation time T_2.

(2) Since the light signal is modulated by the precession at a radio frequency, where the solar cell is insensitive, the photodiode is available for measuring the decay processing signal frequency. Use

the atomic parameters and the processing frequency to determine the earth magnetic field.

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REFORM THE "GENERAL PHYSICS COURSE" TO STRENGTHEN THE PARTS OF MODERN PHYSICS

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In china, the "Gneral Physics Course" for engineering students is an one year course and the teaching hours are about 130 hrs. Its contents include mechanics, thermal physics, electromagnetism, optics and modern physics. According to the most of the textbooks used in China, only one fifth of the whole pages are given to modern physics, the blackbody radiation, photoelectric effect, Compten effect, the wave like properties of particles and Schrodinger equation, etc. Limiting by the teaching hours and the mathematical level of students the discussion is without going into details, also in this part, there are a few problems and questions, and in most cases, it needs students only to use some simply methods and mathematics to solve them. So this part is hardly to hold students' interest. Now, the situation is that starting from mechancis and ending to the modern physics, the course seems to have fine start and poor finish, sometimes, even no finish. If this is the case, the modernization of the contents of General Physics Course is just an idle talk.

On the other hand, the students have learnt physics in middle school for five years, they enter universities with better physics background. They know Newton's Laws and Ohm's Law, but know little about the special relativity. If we only give them classical physics in detail and pass over modern physics, students will ask why the teacher just talk about the things they seem fimilar with and not open the door to the new knowledge they want to know. If things go on like this, the necessary of the existance of General Physics will be in question.

Modern physics, based on the relativity and quantum mechanics, deals with the motion and matter, the structure of matter from dialectical point of ivew, deeper than classical physics. Obviously, it is harmful for training the method of thinking of students if they were lack of the knowledge of modern physics.

Nowadays, the laser, semiconductor etc are widely applying in all the industrial fields. Only for the laser application, for example, there are laserprocessing, laser-quenching, laser analysis, laser equipment for medicine use and holography, etc., it is a long list we cannot go on. So all the engineering students, regardless of their speciality, have to understand the basic mechanism and principle of laser. Similarly, the developing of modern technique is based on the modern physics. We can imagine, the students without the basic knowledge of modern physics and certain training in this field will meet many difficulties after they are graduated from universities. At that time, if they want to make up this missed knowledge, they will spend more time and energy than in the school. In china, no course except physics can give students such knowledge.

Accordingly, we want to reform our course, speed up the teaching and learning process of classical physics and increase the ratio of mordern physics to classical physics. The following is our practice.

1. How to select the contents of modern physics

Because the teaching time is limited, we have to finish physics course in one year. It is impossible for us to include nearly everything like most of the American textbooks of modern physics (e.g. Eisberg and Resnick, "Quantum Physics"), we have to select the things which meet the need for our students. What are in need? On the one hand, special relativity and the element of quantum mechanics are necessary for students to understand the essential of modern physics. On the other hand, because we are teaching the engineering students, it is useful for them to get the basic knowledge of laser and semiconductors. After several years practice, we have chosen the following system:

Special Relativity—Old Quantum Theory—Wave-particle Duality —Elements of Quantum Mechanics—Many-electron Atoms—Laser—Solid State Physics

The distribution of teaching hours is as following:

The review of the developing history of modern physics	1
The particle characteristic of electromagnetic radiation	2
Bohr-Sommerfeld's theory of atoms	4
Debroglie's hypothesis, Heisenberg uncertainty principle	2
Schrodinger equation	4
Many-electron atoms, L-S coupling	6
Lasers	4
Quantum statistics	4
Solid state physics	8

In the chapter of solid state physics, it includes state density, Bloch theory, band theory, the effective mass of electron, p-n junction, etc.

2. How to treat the relationship between classical physics and modern physics

Because the whole teaching time cannot be changed, if we want to strengthen modern physics, we have to reorganize the original teaching plan and contents of general physics. According to the original plan, its includes mechanics, thermal physics, electromagnetism, optics, atoms and nuclears, nearly all the parts of physics, and it wants students to get a full understanding of the objective laws of every motion forms. Yes, it is the one task of the general physics course, but it is not the only aim of the course. Concerning the physics background of the students we have to treat the different parts of the physics with different methods. For the mechanics and waves, the students have learnt these parts in the middle school (of course, without calculus), we use calculus, in order to give students a deeper sight to the concepts and the laws involved. For the electromagnetism, optics, especial the modern physics, the students knew a little about them even nothing, we give more time to treat these parts. According to the practice of recent years, we choose the following distribution:

Mechanics	16-20 hrs
Electromagnetism	38-40
Wave and optics	24
Kinetic theory of gases	6-12

This means that the classical physics can be finished in 84-96 hrs. Plus the 36 hrs for modern physics, the whole course needs 120-130 hrs, it is suitable for the demand of the teaching plan.

From the feedback information from students, these teaching system is different from the old mode, there are many new things attracting them to learn.

3. Some data

During the 1984-1985 Academic Year, we use above system to two classes (160 students altogether). As a part of final examination, we asked students to read some reference materials and then write reports. We suggested following subjects:

1) The meaning of Planck's constant and the experiments measuring Planck's constant.

2) The wave-particle duality and the Heisenberg uncertainty principle.

3) S-L coupling and the experiment methods measuring the coupling between the angular momentums in many-electron atoms.

4) The survey of the band theory.

5) The moving of current carriersin semiconductors and the working mechanism of p-n junction.

6) Bohr-Sommerfeld theory and the periodic table.

7) Lasers and the function of the resonator for gas lasers.

8) Self-selected subject connected with your department.

9) Some different points of view to the concepts described by the teacher.

For the class consisting of students from machinary department and material department, the numbers and ratioes of students choosing diferent subjects are as following:

Subject	1	2	3	4	5	6	7	8	9
Number	12	38	1	6	11	3	32	3	2
Ratio(%)	11.1	35.2	0.9	5.6	10.2	2.8	29.8	2.8	1.8

From this data, we can see that 45.4% students have chosen the subjects concerning lasers and semiconductors. In their reports, they refered many kinds of reference books, including C. Kittel "Introduction to the solid state physics", A.Beiser "Concept to modern physics" M.Young "Optics and lasers" etc. this shows that students are interesting in these contents, they are not grudging the time spent on getting more knowledge. Besides, there are another half students chose 1) and 2) which are the important concepts in the modern physics, especially the concept of duality. One student worte down the following words: "Throught the learning of modern physics, the door leading to understand the law of physical world is opened to us. I feel that before I just took a one-sided approach to see the world, now, the duality shows, there are two sides on one thing, we have to take two-sided view to see the world". But just a few students did 3) and 6), these subjects discuss the basic concepts of the structure of atoms, and are the cornerstones of laser and solid state physics, why a few students chose 3) and 6), do those subjects deal with the pure physics, it is still a question.

How to treat the classical and modern physics in the general physics course is a large project, we will continue our practice to deal with many problems in order to reform our teaching work.

Thanks.

AN EXAMPLE OF THE BASIC EDUCATION OF PHYSICS FOR ENGINEERS

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Yonezawa, Japan

This is an investigation concerned with practical physics education. Basic education of physics is being given to 520 students of maximum admission in our school of engineering as one of the subjects of fundamental sciences.

There are five classes and total credits for students are nine, included an experiment class in the physics course. The main contents of this course are managed by two regular staffs. And three regular staffs and one temporary staff teach the experiments three times a week. So that they are led up to the education of a big mass of students.

In experiments, each of four staffs teach a favorable field among the thermal phenomena, the optics, the electromagnetism and the measurements and proceed the laboratory work with individual idea, that is edition of text book, employing unchanged style or analyses of data with computer use.

These methods of educations have an important effect for synthetic thinking.

DEVELOP THE ROLE OF TEACHING AIDS BY USING DEMONSTRATION, PRACTICUM AND AUDIO--VISUAL PROGRAMS IN OPTICS TEACHING

Wang Bingchao, Gao Jinyue

Abstract

In this paper, the following three topics have been discussed: 1) Bring the role of demonstration teaching aid into full play in optics teaching. 2) The optics practicum is a key link in the training of students' ability of analysing and solving problems. 3) Video is a good means in optics teaching.

SCIENTIFIC METHOD OF INQUIRY VIA PHYSICS LABORATORY USING COMPUTER AS AN AID

Kalpana K Joshi, S.P.College, University of Poona, POONA-7, India.

At a three week computer aided course in scientific method of inquiry and creative problem solving (at school lab.) pupils were exposed to phenpmena involving Archimedes principle, force pressure, electric charge etc. Exploring ideas and forming a hypothesis was followed by initial experiment and group discussion. Discussions involved analysis and design of further experiments. The experience indicated repeatitiveness for teacher. Fear of missing logical link and giving direct answers by teachers has led to interactive computer programme. The Apple-II programs help students in analysis with multiple choice questions leading to different paths, simultaneously evaluates student's understanding of both scientific method and concept involved and also records the score at end.

PHYSICS OF DAILY LIFE AT HIGH SCHOOL

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ABSTRACT

Physics teaching collapsed at brasilian high-schools. Only a minority of private and richer schools students handle the formalism and even fewer understand the underlying concepts. This crisis has social and pedagogical roots. At the University of Sao Paulo, faculty members together with public school teachers identify in high school physics an educational shock due to the formal approach. To overcome this they proposed to start such courses by the study of practical domestic and industrial situations of common understanding. This should be the base for the abstract learning. Officially supported since 1984, this project sends bulletins to thousand teachers, conducts in-service training courses and plans to double yearly the number of engaged teachers.

A RIPPLE TANK DEMONSTRATION OF THE CONDITIONS FOR INTERFERENCE OF WAVES

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I. Introduction

The concept of waves is essential in many parts of physics, such as vibrations and waves, sound, electromagnetic waves, wave optics and wave mechanics etc. It is one of the most general and important concepts in physics. In many aspects of wave phenomena, interference is the common characteristic of all kinds of waves. Historically, interference phenomena have been the means of establishing the wave nature of light.

The ripple tank has long been a very useful apparatus for demonstrating interference phenomena, owing to its good visual effects. Its clear picture helps students to grasp the essense of the concept.

In the traditional method of demonstration, two-source interference pattern is generated by two tips attached to the same vibrator as they tap the surface of water. Accordingly, the waves always have the same frequency and the sources of waves are always in phase. In this way, the conditions for interference are automatically satisfactory it appears to the students that interference of waves can be realized easily, there is no need for a discussion of the conditions. But when we come to the interference of light, it is necessary to introduce the concept of coherent light sources and the importance of the conditions for interference should be emphasized. Here, the students usually find it difficult to have a clear comprehension, especially for the condition of constant initial phase difference.

Students often inquire: "The concept of initial phase and phase difference is an abstract one. How can we have some concrete idea of its physical meaning?" "The acts of light emission from atoms cannot be observed. Why is the failure to observe optical interference attributed to the randomness of light emission from atoms. Does this come from conjectures? Could it be simulated by experiments?" "What happens in the region where two waves coming from incoherent sources meet? What are the results of superposition in this region?" Although teachers may explain all these questions by pure reasoning, yet the students are not satisfied without something to give them more concrete impressions.

In 1982, we tried to use two seperate vibrators driven by piezoceramic plates and obtained interference pattern in the ripple tank. Then one of the vibrators was interrupted by pressing it for random short intervals of time to show the inegular changes of its initial phase. We found that the interference pattern was disturbed, i.e. interference disappeared as a result of the violation of the conditions for interference. But this method is not convenient and it could not give a picture clear enought. The main difficulty is that a mechanical vibrator system has its inertia, so that a transit time from rest to the steady state of vibration always exists. It is impossible to effect instantaneous stops and restorations of the steady vibration. For this reason, to realize instantaneous change of the phase difference, we were obliged to give up the mechanical vibrator system and tried to find some other types of wave sources.

After many trials, we came finally to using water drops as the continuous wave sources, and succeeded in demonstrating interference phenomena and the necessity to satisfy the conditions for interference, namely, the requirments of "constant initial phase difference" and of "equal frequencies" of the two wave sources. It is true, the water drops themselves do not constitute a vibrating system, but they do produce a continuous water wave of definite frequency as they strike the water surface in succession at constant time intervals. For such wave sources, there exists no transit time for their start and stop.

Our apparatus and the various experiments performed are described in the following paragraphs.

II. Construction and Work of the Apparatus

Fig. 1 shows schematically the construction of this apparatus, but here the water supplying device is not shown.

The frequency of the water wave is equal to the number of water droplets falling per sec., which is called the dropping frequency and denoted by . The technical requirements for the apparatus to suit our purpose are as follows: (1) The fall of droplets can be quickly controlled at will. (2) Fine adjustment of the dropping frequency can be effected, and the frequency remains constant long enough for making a demonstration.

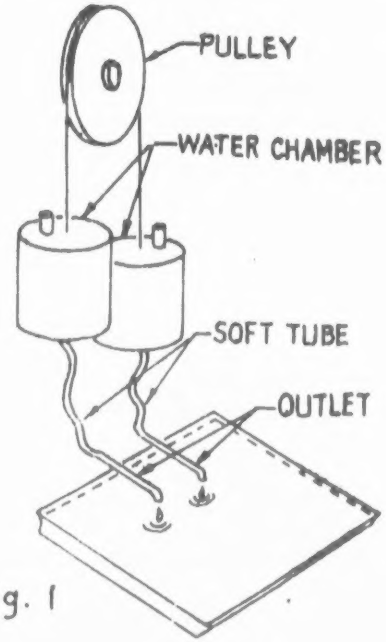

Fig. 1

The water flowing out through the end of the outlet will be constricted. If the diameter of the outlet is small enough, the water does not drop immediately. It contracts at first and then will be expanded to form a sphere approximately until the gravitational force of this part of water equals the force of surface tension at the constriction, the minimum radius γ of which is determined by the circumstances. At this instant, a water drop of volume V is formed and falls off from the outlet. If the density of water is ρ, the coefficient of surface tension is α and gravity is g, we have

$$V\rho g = 2\pi\gamma\alpha$$

This course of formation of a drop repeats itself in definite time intervals

Δt which is determined by the quantity of flow Q through the outlet

$$Q\Delta t = V$$

Hence the dropping frequency is

$$\nu = \frac{1}{\Delta t} = \frac{Q}{V}$$
$$= \frac{Q\rho g}{2\pi r\alpha}$$

If the temperature remains constant, ν depends only on Q. In our design, the water level in the water chamber is controlled automatically to maintain a fixed height with respect to the chamber, while water is flowing into the soft tube. Since the radius and length of the tube are fixed, the piperesistance is constant. Thus the flow Q is determined only by the height of the water chamber above the mouth of the outlet if the temperature of water remains constant, and the required fine adjustment of the dropping frequencies is achieved by carefully adjusting the heights of the chambers.

III. Experiments

We make the following five experiments for the demonstration of the conditions for interference.

(1) Display of the steady interference pattern. This is the same as in traditional demonstrations. But as the two wave sources of our apparatus are not always in the condition required for producing waves of the same frequency, an adjustment is needed. It is only necessary to turn the pulley (shown in Fig. 1) carefully so as to adjust the heights of the water chambers until the equality of frequency is ensured, and the steady interference pattern appears clearly. Students, having seen this adjustment and the course of change of the pattern, will be impressed and will recognize the importance of the conditions for interference.

(2) Demonstration of making changes of the initial phase difference and its effect on the interference pattern. First we show the most common case with initial phase difference zero, i.e. $\Delta\phi_0 = 0$. For this, we adopt the following procedure: with the two sources adjusted as above, the soft tubes are gripped with the fingers, one by each hand to stop the water drops. When the surface of water is flat and motionless, both tubes are loosened simultaneously and the water drops strike the water surface synchronously. The initial phase difference is now $\Delta\phi_0 = 0$. In this case, the steady interference pattern is characterized by the appearance of constructive interference along the central line between the source points as shown in Fig. 2.

Next, we show the case of arbitrary fixed $\Delta\phi_0$. By gripping only one of the soft tubes to stop its water drops, only one wave is left travelling on the water surface. Then the tube is loosened and a steady interference pattern appears again. But it does not coincide with the pattern of $\Delta\phi_0 = 0$. The location of interference maxima and minima changes, because the initial phase difference $\Delta\phi_0$ is changed. When this is pointed out to the students, they will have an idea of the meaning of the initial phases and the effect of their difference on the interference pattern. With a feeling of the dropping frequency and by several trials, one can manage to loosen the soft tube just in time for $\Delta\phi_0 = \pi$. The pattern is now characterized by a line of no motion along the central line between the source points (Fig. 3).

(3) Demonstration of irregular changes of the initial phase difference. The demonstrator makes short grippings on the two soft tubes (one by one alternatively) after irregular intervals of time of about 1-2 sec. These make the two wave sorces to emit wave trains intermittently, the lengths of the different wave trains are different and the time intervals of interruption are different, too. This imitates more or less the acts of atoms emitting light. Fig. 4 is a photo taken in this experiment. It gives us an instantaneous picture of the water wave field, which shows a pattern different from the steady interference pattern of coherent wave sources. It is interesting to note that in the far field, the pattern is similar to the case of $\Delta\phi_0 \cong \pi$, but in the region nearer to the sources, it is similar to the case of $\Delta\phi_0 \cong 0$. The interference maxima and minima are no more lying on hyperbolae but on snakelike curves. As time goes on, the pattern moves forward, and the locations of interference maxima and minima change irregularly.

As soon as the demonstrator stops his random grippings, the pattern resumes its former steady appearance.

(4) Demonstration of the case of two wave sources with small frequency difference. Let us change the relative height of the two water chambers slightly so that the frequencies of the two wave sources have a small difference. A remarkable phenomenon soon appears: the curves of interference maxima and minima rotate slowly about the middle point between the sources. The sense of rotation may be clockwise or anticlokwise, depending on the frequency difference being positive or negative. Fig. 5 is the photo taken in this experiment. The instantaneous pattern differs from all those in the three cases above. Obviously, the lines of maxima and minima deviate from the hyperbolae and curve backward with respect to the sense of rotation. From Fig. 5 we can judge that the curves are rotating in the anticlockwise sense.

Here we observe the phenomena of "beat" in the wave field, i.e. the resultant amplitude at any field point changes with time slowly, so that the lines of maxima and minima move slowly with their tails lagging behind. Now there is no more any steady pattern characterizing interference.

If we slightly turn the pulley to make the frequencies of the two waves equal, the pattern stands still and the steady interference phenomena return.

(5) The case of large frequency difference. By turning the pulley continually, we can see that the pattern rotates faster and faster. At last, we can only see that the waves in the field seem to move in a confused manner, the lines of maxima and minima disappear and the in-

terference phenomenon vanishes.

IV. Notes and Acknowledgement

(1) As the inner radius of the soft tubes is small, the water must be filtered before use to remove any sediments in it.

(2) We have made tests of the equality of the dropping frequencies by an optical method. Laser light passing through the two water falling lines are received respectively by two silicon cells, which are connected to a double-trace oscilloscope. When a steady interference pattern is obtained, the two series of pulses on the oscilloscope completely coincide, which shows that the dropping frequencies are accurately the same. Such steady state can be maintained a few minutes. This is sufficient for a lecture demonstration.

(3) We have brought with us a video-tape record of the apparatus and the demonstrated phenomena, to be shown in the conference. Any suggestions and comments are welcome.

(4) The series of experiments with the use of the apparatus, including the test of the water dropping frequency may be made a subject of the students laboratory works. This will give a good training for the students in doing experiments and making qualitative observations, and it involves many aspects of the usual experimental techniques, such as the use of laser, photo-electric detection and the use of oscilloscope.

(5) Various parts of the apparatus are made by Jang Bing-Lei, the technician of our physics demonstration Laboratory. His help is highly appreciated.

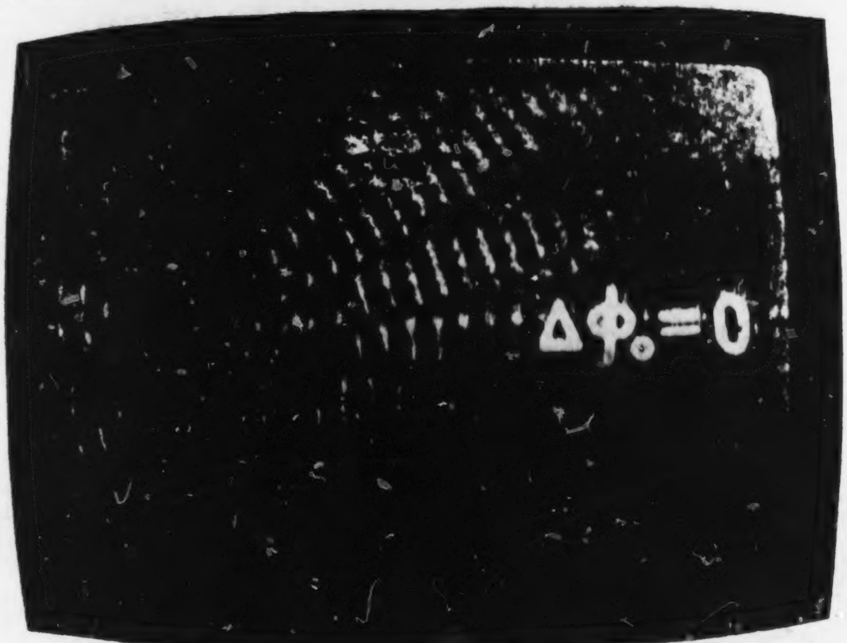

Fig. 2

$\Delta\Phi_0=\pi$

Fig. 3

Fig. 4

Fig. 5

INNOVATIONS IN 5-4-3 SCHOOL SYSTEM
——THE EXPERIMENTS OF JUNIOR PHYSICS TEACHING

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1. Introduction

5-4-3 school system is a system of education that the students study in primary school for five years, in junior mid-school for four years and in senior mid-school for three year. The experimental subject of 5-4-3 school system, curriculums, teaching materials and teaching methods have been endorsed as a countrywide emphasis item of "sixth-five" years plan of scientific research of education. It is launching out in our whole country.

We take part in the innovations and experiments of physics teaching materials and teaching methods in junior mid-school, and advance the theories of the innovations and experiments. We compile the physics teaching materials for the junior mid-school of four-year system, use the textbooks in an experimental class, and meanwhile, probe into the innovations in physics teaching methods in the middle school. The teaching experiments are guided by certain theories. Through the innovation of teaching materials, we give the impetus to the innovation in teaching methods, and then, in the whole physics teaching of mid-school. What we have achieved is as follows.

2. The Basis of the Innovations and Experiments

1). The Principles of structure, Essence and Agility

The principle of structure means when compiling the textbooks, we must select the important materials and stress the basic structure of physics. "Grasping the structure of a subject is understanding it in a way that permits many other things to be related to it meaningfully. To learn structure, in short, is to learn how things are related;"(1) The principle of essence means we should explain the fundamental concepts and laws in physics carefully. Let the students grasp the essential methods of studying physics by observing, experimenting and inferring theoretically; The principle of agility means that the students should learn the material flexibly and integrate theory with practice and turn the basic structure of physics into their cognitive structure.

2). Observation and Experiment First, Thinking next and Practice at Last

Physics is an experimental science. Experiment is one of the important and essential methods of studying physics. The students use their sense organs and the instruments to interact with physical phenomena. They obtain the information of physical world by observing and experimenting. The students' ability of sensation and consciousness is reflected by their ability to distinguish the physical phenomena from many other natural phenomena. Guided by how experienced in their using of the instruments, we may infer from it the developing level of their capability of observation and experiment.

Thinking is the refining process to the students' image which they acquired from their impressions of time, space and matter as well as the interaction between the matter. One of the basic assignments in the middle school's physics teaching is to develop the students' thinking ability. The appearance of the students ' ability is that they are able to judge and reason the image, abstract and generalize the image to obtain the essential characteristics of physical phenomena, and from them, form the concepts of physics, on which, they will get the laws of physics. But the students' thinking of the junior middle school still needs the support of the intuitive impressions.

Practice means using the basic knowledge and methods of physics the students have learned to solve the physics problems. How smoothly, quickly and accurately the students solve the physics problems reflects the students' ability to analyse and solve problems. This kind of ability is also one of the assignments in the middle school's physics teaching. Solving problems means solving not only the problems in the books, but also those in everyday life and production.

3). Interest First, Following by Morale and Will

We should pay more attention to the influence of unintelligence factors in the physics teaching in the middle schools. The students' interest, morale and will in studying physics provide the premised conditions to study physics. The interest of studying physics exists in the students' initiative in studying physics, that is, they are willing to go deeper into studying physics. The morale shows the students' pronounced emotion colour in the study of physics. The will shows the students' determination to overcome the difficulties in studying physics and complete their tasks with indomitable will.

3. The Characteristics of the Teaching Materials

The physics teaching materials in the junior mid-school of 5-4-3 school system (the first stereotyped draft includes three volumes) were finished in May, 1985, and revised on the basis of the first round of use. Liaoning Educational Press published the first volume in August, 1985. The original second and third volumes combined into one volume afterward will be published in August, 1986. The characteristics of the textbooks are as follows.

1). Building the Physics Textbooks of the Junior Mid-school on Observation and Experiment, and Emphasizing the Students' Real Operation

The textbooks introduce the concepts and laws of physics on the basis of observation and experiment, pay attention to cultivating the students' interest and inspiring the students' thinking. Each part of the textbooks is introduced by "OBSERVATION AND THINKING", "OBSERVATION AND EXPERIMENT", "EXPERIMENT AND THINKING", and so on. It emphasizes the students' own operation. For example, the volume of electricity provides many experiments for the students' own operation, arragnes thirteen simple experiments and twenty-four exercises for observation and experiments by themselves after class. The students can do experiments themselves not only in the laboratory, but also from the all aspects of their daily life. In order to help them to understand the relation between physics and living, the teaching materials ask the students solve their own problems.

2). Integrating the Structure of Physics with the Cognitive Structure of Physics and Paying Attention to the Use of Various Students

The Structures of the physics teaching materials differ from the one of physics as an exact science. It is confined by the students' congitive level, time of studying, teachers' level, and so on. For this reason, the narrative orders of the textbooks must be arranged reasonably. For example, the electricity part begins from circuit, not from triboelectrification as in the traditional teaching. This selection is due to the students' preliminary knowledge of the basic phenomena in the primary school. Beginning with circuit is to learn the electrical macrophenomena. Keeping the students in close contact with the everyday life can arouse their interest helpfully. After the students have grasped certain basic knowledge, electron in the modern physics will be introduced in order to explain circuit from the microscopic point of view. These can lessen the difficulty in starting the lesson of electricity in the junior mid-school. In the part of the magnetic field the textbooks stress on the relations between current and magnetic fields, deal with the magnetic field of permanent magnet as extra contents of the magnetic field of current. These are in accordance with the students' knowledge level and experience. Electric work is both difficult and important in the junior mid-school physics. In order to relieve the difficulty as much as possible, the textbooks adopt the method proceeding from the special to the general cases. For instance, the textbooks introduce the special case of electric work——Joule's Law —— in the first which provides the necessary materials for electric work. Then the textbooks introduce electric work with comparable ease. These are the different order from ordinary textbooks.

In depth, the textbooks keep the level of the original ones in the three-year junior mid-school. The textbooks expand the contents in the range of knowledge and pay attention to the methods of introducing of the concepts and laws of physics. We integrate/the textbooks' structure with the students' cognitive structure and arrange a lot of reading materials (18 items in electricity) for further study of various students.

3). Be Favourable for the Innovation in the Teaching Methods

The textbooks provide convenient conditions for the use of various teaching methods. The students' real operations, qualitative discussions, exact theories, demonstration experiments by teachers, interesting exercises and the materials of the physics history, and so on, are arranged in the textbooks. The students' own observation and experiment are the basis of studying physics. We only introduce the train of thought of experiments, the physical phenomena and the conclusion, but not the experimental data in studying the essential concepts and laws of physics. For these, the teachers and the students must perform experiments by themselves. All these push the innovations in the teaching methods forward.

4. The Innovations in the Teaching Methods

After the summer vacation in 1983, the experimental textbooks came into use in the experimental class of 5-4-3 school system in the 2nd Attached Middle School of Beijing Normal University. Now it goes into the second round. The textbooks are tried out in many provinces and cities in China. We applied some parts of the textbooks and explored the use of various teaching methods in teaching practice.

The fundamental demand of physics teaching metods in the middle school is: to keep touch with living based on observation and experiment, to inspire the students' interest, to take note of the students' feedback information and to change the structure of physics into the cognitive structure of the students.

Lecture-demonstration method: It is most applied method in physics teaching, namely, teaching the students physics with lively language, materials of sense-perception and demonstration experiments. On the basis of this method, we inquire into other teaching methods; such as:

Study-discussion method: It is suitable for the contents which are in touch with living closely. When applying the method, the teacher works out questions, provides for the students the necessary instruments, and then divides the class into some groups. The group leader should take charge of the instruments and the organization of the discussion. The students look up materials in books, discuss questions and carry out experiments by themselves. The teacher asks one student in each group to answer the questions and provides the necessary supplements and explanations.

Lecture-practice method: It applies to the seminar and the class for the use of the general instruments. For example, when studying the use of stopwatch, thermometer, ammeter, voltmeter and other basic instruments, the teacher distributes the instruments among the students. These can bring the students' sense activity into play. The students can grasp the structure of instruments quickly and easily.

Direction-discovery method: It applies to teach the essential concepts and laws of physics. When using the method, the teacher may distribute the instruments to the students, let them make the designs of experiments, do experiments, get data and conclusions by themselves. The role of teachers is to guild the direction of the students' experiments and to help them correct the errors in order to make the students get the right conclusions.

It is a good method of seasonable feedback that it takes few minutes to make a brief test in the lesson. The teacher can know the students more extensively and reliably by the test. He can teach the students more successfully.

The classroom structure becomes smaller with the innovations in the teaching methods. This position is advantageous to arrange the teaching according to the students' personality, so as to strengthen the interactions among the students, and to ensure the exchange of information between the teacher and students. We must notice that no teaching method is all-powerful, and there is not any unique model in the teaching methods, so various teaching methods should be used synthetically in the practical teaching process.

5. The Achievements in the Innovations in the Physics Teaching

The second, third and fourth grade in the junior mid-school offered physics ources in the first round of experiment and the third and fourth now. With the help of the leaders, teachers and auxiliary staff memebers of teaching, we have got some achievements.

1). The Students' Interest of Studying Physics

After the students finished the course of physics in the junior mid-school we planned two question-list to investigate the students' interest in the experimental class. One is open, which asks the studetns to write down the reason why they like or dislike general physics. The other puts forward ninetedn questions for the students' choice. Every student is asked to finish the lists. Every list has 42. We take back 42 X 2 copies. They are all effective. The results of the investigation are: there are 33 students who do like physics, which makes up 78.58 per cent, 9 students who like physics in general sense, which makes up 21.42 per cent, no one dislikes physics. All of these illustrate that the innovations in the physics teaching is successful.

2). The Developing of the Students' Cognitive Ability

According to B. S. Bloom's classification to cognitive, we classify the objective simply into three class: memory, understanding and solving problems. Owing to real operation being one of the cognitive objective in teaching physics, we think that memory, understanding, application and real operation are the cognitive objective. We test the students' cognitive ability for each chapter of electricity. The results are showed in table 5-1 and table 5-2.

TABLE 5-1 The coefficients of correlation between each factor and total scores

	chap.1	chap.2	chap.3	chap. 4&5
memory	0.46	0.55	0.73	0.91
understanding	0.90	0.88	0.89	0.48
application	0.83	0.85	0.53	0.94
real operation	0.70	0.89	—	0.85

TABLE 5-2 The reliability and validity of each test

	chap.1	chap.2	chap.3	chap. 4&5
reliability coefficient	0.61	0.59	0.54	0.71
validity coefficient	0.72	0.79	0.7?	0.79

From the results we know the coefficients of correlation between each factor and the total scores are higher ones. For this reason, the developing of the students' cognitive ability is coordinated.

3). The Students' Scores

The first four-year junior mid-school experimental class in the 2nd Attached Mid-school of Beijing Normal University started school in 1982. The experimental class was a common class at the beginning. It is a middle level in Beijing. The compare classes were fine ones. They were the high level in Beijing. The teachers teaching the experimental class are young ones. They get the help of experienced teachers. Consequently, the average rate of the fail of the experimental class is 2.26%, the compare class-1 2.20% and the class-2 3.58%.

In the compare examination held by Dept. of General Education of Beijing Normal University the experimental class came up to the compare classes' standards. The results are showed in table 5-3.

TABLE 5-3

class	No. of fail	average scores	reliability
experimental class	3	81.17	0.77
compare class-1	3	82.6	0.62
compare class-2	4	77.21	0.66

All these tell us through the several years experimental teaching the students of experimental class get better scores.

4). Extracurricular Activities and Others

The students of experimental class show not only their high initiative of studying physics in class, but also active studying atmosphere after class. They constituted several groups of radio, the group of astronomy and the group of spaceflight etc.. Some of them took part in the competition of the first Beijing City junior mid-school physics experiment in 1986. Among all the attenders in the 2nd Attached Mid-school, only two students of the experimental class get the finals.

As stated above, the innovations and experiments based on the theories are successful. Our work belongs to a middle standard innovation. Because of the restrictions on the objective conditions, we can not change the most of the teaching contents. The theories of innovations should be further perfected.

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KNOWLEDGE AND EXPERIENCE ON TEACHING SELECTED PAPERS ON THE FURTHER READING OF GENERAL PHYSICS

——EXPLORATIONS OF RATIONAL KNOWLEDGE AND ABILITY

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1. INTRODUCTION

At the present time which sees the swift development of science and technology and the rapid increase of the amount of knowledge, it has been an urgent matter of common interest and concern for study and exploration in colleges and universities to accomplish the rationalization of both imparting knowledge to the students and fostering their ability to master it in order to train and bring up a large number of pioneer, high-level engineers and technicians who can successfully shoulder the heavy responsibility for creation in developing scientific research.

Physics is the Kernel of Science, the basis of all engineering and the starting point of growth of new and developing courses. The positional importance of the essential theories of physics in the structure of modern knowledge should be stressed. Moreover, in imparting physical knowledge to the students, it is of more profound significance to foster their mode of thinking, attainment and approach in physics; besides, we should further notice that the knowledge the students need in their work in future mostly depends on the application of the founded essential theories which they'll obtain through their independent study. This has led some educationists to point out sharply that the college student would be a new illiterate if he has no ability to study on his own and that he can in no way keep abreast of the rapidly developing situation of science and technology. Therefore, we must emphasize the fostering of the students' ability and in particular place before everything else the fostering of their ability to study independently while imparting knowledge to them.

General Physics , as a major course of essential theories in institutions of higher learning, functions as a role of vital importance in fostering qualified scientists and technicians; but on the other hand, it must be noted as well that the students' range of knowledge will be widened as a result of the wide range of the teaching content, the method of conducting lectures, the scheduling of hours, etc. However, there's a restriction to a certain degree in teaching the most recent theories, in applying essential theories, and especially in fostering the students' ability and scientific attainment. These are the very problems that the students feel most interested in and they energitically and enthusiastically long to solve them under the new circumstances of science and technology. To offer this course is a scientific exploration carried out in an attempt to settle the above mentioned problems of fostering the students' ability and encouraging them to acquire knowledge so as to meet the needs of the new situation of science and technology for training and bringing up qualified scientists and technicians.

To this end, 《Selected Papers on the Further Reading of General Physics》 has been offered after the students have studied general physics (class hour: 17×1 per semester). In exploring both the imparting of knowledge to the students and the fostering of their ability (especially, the ability to study independently), some superficial knowledge and experience has been gained. And at the same time, some feedback information has been obtained about the evaluation of the quality of teaching and learning of physics, which furnishes some source material of reform in education.

2. Widening the Range of Knowledge of Essential Theories and Strengthening Modern and Applied Physics

The students who have finished general physics have already understood and grasped to a certain degree of depth and range the basic forms and laws of the motion of matter; therefore this course is based on the principle of selecting material to widen the range of knowledge of essential theories, strengthen Modern and Applied Physics and provide the forward knowledge to suit and meet the needs of the situation of up-to-date science and technology, etc. As usual, the content selected and compiled herein consists of several units according to the traditional system of physics and it is divided into two parts.

Part One deals with classical physics and its application, including widening and deepening the knowledge of classical theories and making an approach to the problems of concern and interest in common among the students, etc (e.g. The problem of the work and heat transfer in the sliding friction; the research of variable Mass problem for the uniform rope sliding over the edge of a smooth table, etc.); the way and thinking of the simple demonstration of some basic laws (e.g. The Coulomb's Law) and the wide-ranging application of classical theories to modern production and life (e.g. The applications of rotational inertia and compound pendulum, the determination for translation speed of a plate and the measurement for vibrational frequency of machine tool using Doppler's method, etc.

Part Two is concerned with modern physics and its application. Besides a deeper understanding and an impressional description of the basic concepts and laws of modern physics (e.g. Graphical introduction to the special theory of relativity, Observational evidence for atoms, Experiment and the nature of quantum reality, etc), articles compiled herein comprise the knowledge extant in production and science and technology and new scientific and technological achievements and their application (e.g. Microchannel plates, Solar energy, the application of the Nuclear power and Super-conductivity, etc).

The whole teaching material which consists of twenty-one documents of scientific and technological literature has been chosen from the English and Japanese magazines concerned. The data selected deal with the knowledge in each and every aspect of physics, but the documents picked are not arranged in order of difficulty but they are arranged as individual topics because they are independent of each other, and therefore some of them may be chosen as required source material on the basis of the students' knowledge attained and the teaching hours planned, and leave the rest as reading material for outside the class for those who are able to read them.

3. Exploration of the Fostering of the Ability to Study Independently

Literature search and the reading of reference material and scientific and technological literature are an important aspect of engaging in research and innovation as well as an indispensable means to foster the ability to acquire knowledge independently. At the same time, it should be noted that the ability to read foreign, chiefly English literature of science and technology is a kind of basic skill and an important tool for the would-be scientists and technicians to collect information make academic exchanges and raise their competitive ability Hence it is necessary to give the students hight from the beginning a training of such fundamental skills so as to create favourable conditions for constantly raising their ability to search literature, read reference books and translate English documents and data during the latter part of their stay in the university. This is a very effective measure in that it enables the students to obtain knowledge extensively during their university days and also fosters their ability to study indenpendently in future. Such a training will certainly benefit the students a great deal.

Thus, the fostering of the student's ability to study on his own is highly stressed in the course of English scientific and technological reading with the teacher playing merely a guiding role. The students are required to read the papers earnestly and express their views freely on the basis of independent thinking. In this way they can learn from each other. In the first introductory lesson, the teacher distributes among the students leaflets containing the aim and demand of the course, the teaching plan, the way of conducting classes, examinations, etc, so that they may adjust the time outside the class, plan the progress of their reading and work at the course with full initiative. For instance, a class of sixty-one students is divided into eight groups. Before class, every student is expected to read through the papers seriously as scheduled in the teaching plan. The groups are to take charge of the classroom discussion in turn. From each group a student is chosen to make a central speech, summing up the general idea of the paper to be discussed and making comments on it. After that, he is to raise some questions of common interest for discussion in class. Then this central speaker is to write out a summary of the discussion in English.

What counts in the course of teaching is the leading role the teacher plays. Before class the teacher must, by making an indepth analysis and careful induction of the content of the paper, find out the parts understandable to the students through independent study and the problems that can be grasped thoroughly only as a result of group discussion. He must also find out the problems that are difficult for the students to solve at their present level. Then the teacher is to make use of the last twenty munites of each lesson to set some questions for discussion concerning the problems to be dealt with in the next period. By so doing he points out the places that should be brought to the students' attention, with regard to some general problems that are still beyond the reach of the students, the teacher may just drop them a hint, or recommend them some reading material. For example, in the course of reading the paper Graphical Introdution to the Special Theory of Relativity VI, Pole Vaulter Paradox, the teacher may raise the following questions pointedly:

1) What's the most important experimental events and orders of the paradox designed in the paper?

2) Why does the experimentalist standing on the platform flying at 99.5 percent of the velocity of light conclude that he's about to be sacrificed to science?

3) How does the experimentalist give his explanation of this unexpected outcome (i.e. how does he work out the resolution of the apparent paradox?) etc.

The students are required to answer the first two questions by studying on their own, but as for the third one, they're asked to make an analysis of it with the help of the method of the space-time map and the Lorentz Transformation Formulas separately and resolve the paradox through group discussion on the basis of the teacher's brief introduction to the medium for research of the special theory of relativity of the space-time map. In the course of teaching we've found the students, owing to a lack of practice in reading and translating English scientific articles and especially owing to their limited vocabulary in science and technology, still can't read fast enough, nor can they fully understand the reading material although they have learned the basics of daily English and some of them can even read English novels. Therefore, at the beginning, the teacher is to give the central speaker some individual coaching before class and set him some enlightening questions. While in class, after the central speaker has made his speech and when the classroom discussion is over, the teacher must give a fairly detailed explanation and analysis of those involved sentences so as to help them overcome any fear of difficulty that may arise at the initial stage. Of course, with the students' growth in competence the teacher's explanation can be cut down and the students' self-study be emphasized. During the whole course of teaching, different demands should be made of the students at different stages of development. Take the reading of part one of the selected papers, emphasis is laid on the fostering of the students' ability to read English literature of science and technology. Later, the students are required, while reading part two of the selected papers, to shift their attention to the comprehension of the concepts of physics contained in the documents so as to achieve the goal of widening their range of knowledge and strengthening their knowledge of modern physics, applied physics and the latest development of science and technology.

4. Results and Suggestions

The students worked with all their energy and the enthusiasm in their students ran high in the early stage of the course owing to their understanding of the significance in the reading of foreign scientific and technological literature. All of them read through the prescribed documents carefully and seriously and held heated discussions among themselves though they had difficulty in the fact that there were many new words and expressions that gave rise to the slowness of the reading. They strove to understand the involved expressions truly and with accuracy. The student chosen as the central speaker made special efforts and spared no pains to prepare in all respects such as the reading of the foreign papers, the content of physics, etc. He talked thoroughly over the problems as soon as he found them with teachers and other students and also read some other reference books and data that helped to understand the problems. The other students, too, read and studied the prescribed papers conscientiously and assiduously. In so doing, the accumulation of the vocabulary developed and increased and the reading was going at a gradually accelerated pace as well. And furthermore, their major effort, which was confined to the translation of the scientific and technical foreign language in the beginning, was gradually concentrated on the discussion of the physical concepts after their ability to read being developed. They could relate what they'd learned in general physics and associate all their knowledge, new and old, to get a thorough understanding of the documents. More and more they felt interested in and confident of the course. For example, in the article Work and Heat Transfer in the Presence of Sliding Frication as long as seven pages, the first problem they came across was that there should be something incorrect in the calculation problem of the work done by frication forces, which was always thought to have been correct ever before. The cause of the incorrectness turns out to be the fact that the energy conversion is neglected. This tells them that only when it applies simultaneously the mechanical equation and the first law of thermodynamics could a perfect conclusion be reached. Consequently, through the reading, the students' range of knowledge has been widened and their ability to expound and solve physical problems all-sidedly has been improved. The students have also learned from experience in the reading of the documents that the laws of classical physics are still the making of the scientific and technological production nowadays. They feel what they've been studying is useful and applicable and understand the role and prospect of the application of modern physics to solving the problems of engineering, especially after they've studied the literature of modern science and its application concerning their own speciality. They commonly welcome and highly appreciate "exercises under battle conditions" with live ammunition of that kind.

Around the middle of the semester, classwork was orgnized once, which took the Double and Multiple Quantum Photoelectric Emission as the topic for discussion based on the reading of the documents concerned. In the classwork, some questions in illustration of the main grounds of argument in the documents were put to the students and they were required to answer them in written form. The questions were as follows:

1) Can a free electron absorb a photon and electrons in what state can absorb photons to bring about photoelectric emission? Why?

2) Try to analyse the possible realizability of the double quantum photoelectric emission in the light of the basic theories of quantum-mechanics.

3) The application of double quantum photoelectric emission to the modern industry in prospect.

4) Which points of view in the document do you think are not precise enough and what's your arguments? What form will the A. Einstein equation and threshold value take after the realization of the double and multiple quantum photoelectric emission? etc.

In working out these problems, not only did we achieve the goal of checking up the students' ability to read, but we also guided them in the application of the essential knowledge learned in general physics to the further study in and approach to the basic laws of physics. It has enabled the students to understand the fact that no knowledge and laws immutable and that they'll renew themselves uninterruptedly and continually with the development of human society as well as that of science and technology and has enlightened them on the spirit of seeking truth and the spirit of innovation.

The opening of the course 《 Selected Papers on the Further Reading of General Physics》 has made it possible for us to counteract the deficiency existing in the imparting of knowledge and the fostering of the students' ability to master it in the practice of teaching general physics and guide their methodology. This has greatly inspired the students' enthusiasm is their studies and their thirst for knowledge and increased their ability to read. The gains will certainly be immense in the fostering of their ability to acquire knolwedge independently so as to suit the needs of their work in the future. And through the practice of the teaching of the course, some feedback information has been obtained about the evaluation of the quality of teaching and learning of general physics.

However, the course 《 Selected Papers on the Further Reading of General Physics》 is nothing else but a try. Both work done and experience gained are superficial and rudimental. It can only be regarded as a course of approach and introduction, especially because of the limited class hours. From now on, in accordance with the students' ability to read foreign documents of scientific and technological literature as the case stands, it is suitable to select material gradually from the easy to the difficult and follow in order and advance step by step. In regard to the selection of foreign literature, we plan to add still more kinds of foreign languages such as Russian, etc. with the kinds of the students' first foreign languages on the increase. We also believe that if the course of selected papers on the further reading of general physics is organically combined with that of general physics, or if several reference documents corresponding to each chapter of general physics further readable to the students are recommended to them, we will surely strengthen in content the modern theories and their application, widen the students' range of knowledge and gradually foster and train the students' ability to study on their own, especially their ability to read scientific and technological literature in foreign languages. This would provide the orientation and possibility of innovation and reform in the course of general physics so as to satisfy the students' thirst for knowledge and arouse the initiative and enthusiasm in their studies. It may be well expected that the reform in general physics which caters to the need of the new situation of science and technology will take on an entirely new aspect.

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GUIDED-WAVE LIGHT AND ITS CHALLENGE TO OPTICS

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(I) Introduction

With the development of optical-fibre technologies, particularly the optical-fibre communication technology and integrated optics, it is necessary to give systematic lectures on guided-wave light to the undergraduates and post-graduates who major in electric and electronic engineering, radio and microwave engineering, applied physics and physics. Experiments show that the linear propagation properties are much more remarkable for guided-wave light than for non-guided-wave light. Eikonal equations are much better suited for guided-wave light than for non-guided-wave light. Although the diameter of the optical fibre is very small, guided-wave light propagating therein has an attenuating loss somewhat around 1dB/km or even less. The guided-wave light essentially does not diverge, showing very little diffraction, much less than the parent laser beams. Guided-wave light in optical fibres possesses the properties of one-dimensional plane waves of the form $e^{i\beta z}$ where z is the axial direction of the fibre.

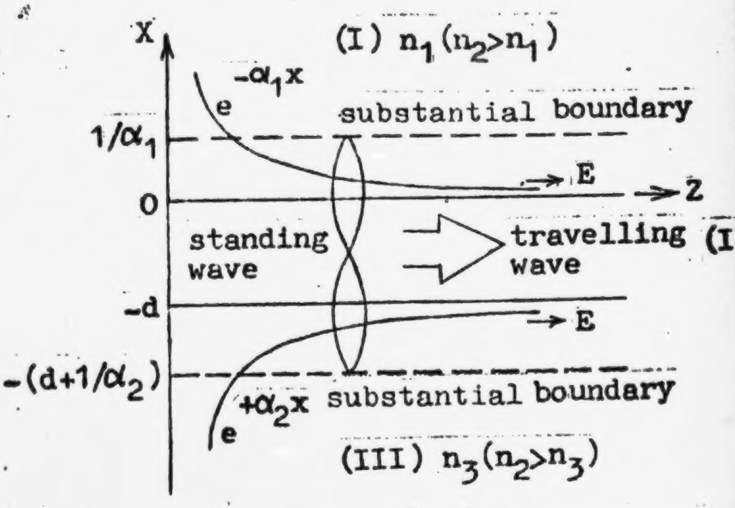
The present-day prevalent books on guided-wave light are such as Introduction to Integrated Optics, ed. by M.K. Barnoski, Plenum Press (1974) and Integrated Optics, ed. by T. Tamir, Springer-Verlag Berlin Heidelberg, New York (1975) contain chapters to treat guided-wave light in optical fibres by the usual method of ray optics. Engineering students have not had any doubt on the method of treatment. But the serious students of physics raise a lot of questions. They argue, as the core diameter of the optical fiber is only a few microns and is of the same order of magnitude as the optical wavelength (λ=1.3 or 1.55 um), how can ray optics be applicable to guided-wave light ? Guided-wave light in optical fibres is really one-dimensional plane waves, but light radiations usualy obey Huygens' Principles and can not be one-dimensional plane waves in the bounded space. The optical guided-wave $e^{i(\beta z-\omega t)}$ can not be solved as a solution of the electromagnetic wave equation $\nabla^2\vec{E}(\vec{r},t) - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\vec{E}(\vec{r},t) = 0$ subjected to any boundary conditions. The present—day prevalent textbooks on guided-wave light just take the guided-wave solution for granted and only discuss actually the modes of the optical waveguide. Light can not turn into optical guided-waves by itself. Students of physics are quite dissatisfed with that the present-day textbooks in this field have not discussed the mechanism of formation of the optical guided-wave and totally overlook the physics aspect of the problem. Besides there are in the mentioned books quite a few confusions in physical notions.

All these doubts and questions came to me and made me quite perplexed. Once, I inserted the solution $e^{i(\beta z-\omega t)}$ into the electromagnetic wave equation and happened to find the fact that optical guided-waves could not be formed unless the incident laser light was assisted somehow by the quasi-particles of the waveguide materials. In 1979, I put forth a viewpoint that "the optical guided-wave is the result of the hybridization (coupling) of the incident light with the elementiary excitations[1,2] of the waveguide." Then I asked a few post-graduate students of physics to work on this viewpoint and they obtained very good results in their master theses[3, 4] Beginning from 1982, we started to work optical guided-wave problems on the quantum-mechanical basis, i.e. The Polarition Theory of Guided-Wave Light.[5,6,7,8] Since then we have published over 50 papers [3-11] on the the guided-wave light including 3 doctoral theses.[11] We have now actually established a systematic theory on the optical guided-wave problems. In the following, I'll try to give a physical sketch of the theory.

(II) Field Distribution of the Guided-Wave Light

In Fig. 1, the field distributions of an optical slab waveguide (with crystaline or amorphous dielectric medium) are schematically shown. (I) represents the clad, (II) the film of the guide and (III) the substrate and n_1, n_2 or n_3 is respectively their refractive index, with $n_1 < n_2 > n_3$ the condition of total reflection being satisfactory When the guided-wave light propagates in the waveguide, there exist the evanescent field of the form $e^{-\alpha x}$ in both the I-and the III-regions. The field intensity at $x=1/\alpha$ falls to e^{-1} of that at $x = 0$. That is to say, $x = 1/\alpha_1$ and $x = -(d + 1/\alpha_2)$ forms the substantial boundaries of the waveguide, where d is the thickness of the waveguide film. The attenuation coefficient α of the evanescent field is equivalent to the imaginary wave vector (ik), thus the evanescent filed is the wave field of non-radiations. Light is electromagnetic radiation and light field is naturally radiating field. Why is there wave field of non-radiations (the evanescent field) in the field distribution of guided-wave light? We are of the opinion that the evanescent field is the indication of the wave field of the electromagnetic elementary excitations of the waveguide film outside the boundary and hence the field intensities die away according to $e^{-\alpha x}$. We are going to see, the existence of the evanescent field is really an indication[4,5] that the guided-wave light is the reslt of the mixing (the hybridization) of the material elementary excitations with light radiations.

As the waveguide is covered with (or surrounded by) evanescent fields of non-radiations, energy in the waveguide will not radiate and is confined within substantial boundaries. As a result, the optical waveguide is characterized by the fact that the energy is localized up and down transversally and can only propagate (extend) longitudinally. In other words the travelling wave in the longitudinal direction is always accompanied by the standing-wave field. i.e. the modal field.



The existence of evanescent fields is the vital factor[7] to form optical guided-waves and this serves also indications that material elementary excitations of the waveguide play important roles in the formation of guided-wave light.

(III) Roles played by the Elementary Excitations in the Formation of Guided-wave Light.

In order to understand more easily, we just adopt the classical electromagnetic equations to illustrate the influences of the elementary excitations of the waveguide in the formation of the guided-wave light. As a matter of fact the appearance of the modal fields marks the contributions of the elementary excitations. In our systematic theory, we have strictly testified with the Green function method [7] that modes of the optical guided-waves are in fact a part of the spectra of the guided-wave polaritons. In the following paragraphs, we would show the roles of the elementary excitations.

When the electromagnetic wave propagates in a medium, the wave equation is given by

$$\nabla^2 \vec{E}(\vec{r},t) - \frac{1}{v^2}\frac{\partial^2}{\partial t}\vec{E}(\vec{r},t) = 0 \qquad (1)$$

For the harmonic wave we have

$$\vec{E}(\vec{r},t) = \vec{E}(\vec{r})e^{-i\omega t} \qquad (2)$$

With the substitution of (2) into (1), we obtain the steadystate equation

$$\nabla^2 \vec{E}(\vec{r}) + k_0^2 n^2 \vec{E}(\vec{r}) = 0 \qquad (3)$$

where n is the refractive index of the medium, and $k_0 = \omega/c$ is the wave vector in vacuo.

For the planar waveguide that extends along the z direction (and $\partial/\partial y = 0$), the optical guided-wave is given by

$$\vec{E}(\vec{r}) = \vec{E}(x)e^{i\beta z} \qquad (4)$$

and the substitution of (4) into (3) results

$$\frac{d^2\vec{E}(x)}{dx^2} + (k_0^2 n_i^2 - \beta^2)\vec{E}(x) = 0 \qquad (5)$$

where i = 1 stands for clad, with n_1 the refractive index of the cladding material. i=3 stands for the substrate and n_3 is the index of the substrate. As $n_1 < n_2 > n_3$ where n_2 is the refractive index of the waveguide film in both the clad and the substrate regions, E(x) 's are of the form $e^{-\alpha x}$ and are the evanescent fields. In the waveguide film (i = 2), we have

$$\frac{d^2\vec{E}(x)}{dx^2} + (k_0^2 n_2^2 - \beta^2)\vec{E}(x) = 0 \qquad (6)$$

This is the equation to determine the modal fields. In order to get the oscillatory solutions of (6), that is to form the modal fields, the term $(k_0^2 n_2^2 - \beta^2)$ must be positive, and so let us set

$$K^2 = (k_0^2 n_2^2 - \beta^2) = k_2^2 - \beta^2 \qquad (7)$$

where $k_2 = k_0 n_2$ is the wavevector of the light in the waveguide. From (7), we find that $\vec{K}$, $\vec{k}_2$ and $\vec{\beta}$ satisfy the following relation

$$\vec{K} = \vec{k}_1 - \vec{\beta} \qquad (5A)$$

that is

$$\hbar\vec{\beta} = \hbar\vec{k}_1 - \hbar\vec{K} \qquad (8)$$

where $\hbar\vec{k}_1$ is the momentum of the photons that enter the film, $\hbar\vec{\beta}$ is the quasi-momentum of guided-wave polaritions and $(-\hbar\vec{K})$ is the quasi-momentum of quasi-particles in the guide. From (8) we may find that it is not possible to form the modes of optical guided-waves unless the incident photons are somehow assisted (interreacted) by the quasi-particles. As the evanescent field is accompanied by the interaction, we can infer from (8), that the interaction consists in the coupling of the quasipartioles of the electromagnetic elementary excitations (To phonons or excitons, etc) with the photons. For this sort of hybridization, our systematic proofs have been published in the J. Appl. Sci. (in Chinese) [6, 7, 8]

Since the guided-wave light is the consequences of the hybridization of the elementary excitations in the waveguide (optical fibre) with the incident light, it is certain that the guided-wave light possesses the dual properties of the material elementary excitations and the electromagnetic radiations. Thus, the guided-wave light is not composed of photons (the pure state) but rather polaritons (the mixed state). Naturally, classical electromagnetic theory is not always applicable to treat problems of guided-wave light.

(IV) Phase-transition Analog [9] of Guide-wave Light, Ordering of Polariton Momenta

Since the formation of the guided-wave light is the result of the coupling of the elementary excitations with the incident light, and photons of the pure state converts into polaritons of the mixed state, the coupling (hybridization) brings about the essential changes in the structures as well as properties (features) of the light quanta. These microscopic changes must be reflected macroscopically. So we guess that, there must be changes in the states (polarizations) and in the structures (field structures). Through observations and analysis, we find just what we expect. The incident laser light transforms into guided-wave laser light with characteristic features just like those when water transforms into ice. Thus, we call the process during which guided-wave light is formed as phase transition analog, i.e., these two kinds of processes bear resemblance.

Water is an isotropic substance while ice anisotopic. As far as symmetry is concerned, water is of higher symmetry than ice. When water converts into ice, symmetry becomes lowered. There is symmetry breaking [9] during phase transition. Symmetry breaking is always an indication of phase transition.

We are going to show there is symmetry breaking in the electromagnetic field when incident light converts into guided-wave light. [9]

In general, optical waveguides such as optical fibers are dielectrics. There are no free charges $(\rho = 0)$ and no conducting currents

$(\vec{j} = 0)$ and we adopt orthogonal coordinates. Thus, the electromagnetic field equations are:

$$\nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t} \qquad \nabla\cdot\vec{D} = 0 \qquad (9)$$
$$\nabla\times\vec{H} = \frac{\partial\vec{D}}{\partial t} \qquad \nabla\cdot\vec{B} = 0$$

Imagine that subject these equations an operation $\hat{\varphi}$ (see Fig. 2) so that

$\vec{E} \rightarrow \vec{H}$, $\vec{H} \rightarrow \vec{E}$

$\vec{B} \rightarrow \vec{D}$, $\vec{D} \rightarrow \vec{B}$

and

$t \rightarrow -t$

$\vec{k} \rightarrow -\vec{k}$

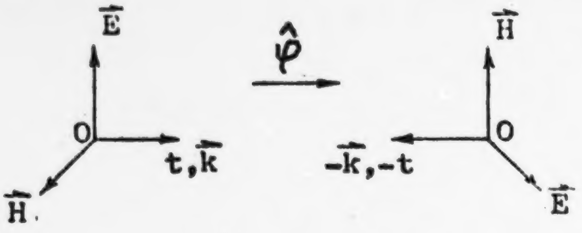


Fig.2 Operation $\hat{\varphi}$

For TEM wave, the operator $\hat{\varphi}$ does not change the system of equations as a whole, the electric field and the magnetic field being completely symmetric with each other. While for non-TEM waves, (such as TE or TM waves), one will find that the electric field and the magnetic field are no longer symmetric with each other under the operation $\hat{\varphi}$. When incident TEM laser light converts into guided-wave laser light, it becomes non-TEM. There is symmetry breaking in the field structures and this an indication that the process (the hybrdization) is a phase transition analog.

Besides, in phase transitions, symmetry breaking is usually accompanied by changes of degree of order of a certain kind. Broadly speaking, in the process of phase transition, if the symmetry becomes lowered, the degree of order of some kind must become higher. Let us illustrate this by taking also the water-ice transition as an example. Water is liquid and its structure is random and isotropic. While ice is a crystal, the molecules within ice constitute periodic space lattice and its structure is of longrange order. Therefore, when water turns into ice, symmetry becomes lowered and in the meantime structure becomes ordered. In the solid-state physics, there are a lot of similar examples. Let us give a well-known example $BaTiO_3$, a ferroelectric crystal. When the temperature is above 120°C, $BaTiO_3$ is of the cubic structure and there is no electric domain in the crystal. If the temperature falls close to room temperature 20°C, $BaTiO_3$ crystal turns inte tetragonal structure, and in the meanwhile there appears in the crystal the electric domain. The formation of the electric domain indicates the order of the electric polarizations, i.e. electric micro-dipoles line orderedly. Hence, when the temperature falls

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and

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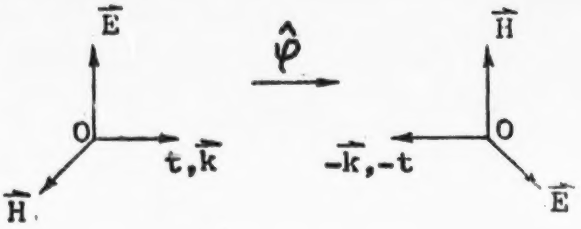

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In the case of guided-wave light, as a consequence of the fact that the symmetry of electromagnetic field becomes lowered, the degree of order of some kind must become higher. We infer that the quasi-momenta of the guided-wave polaritions become long-range-ordered. This is the reason why the linear propagation properties are extraordinarily good and laws of ray optics govern, in the case of guided-wave light.

Through these researches, we also recognize that there exist a lot of parallelisms between the guided-wave light and the superconductivity.

(V) Outlooks

With the rapid devolopment of technical sciences, there bring about a lot of physical problems so new, so intricated, so wide and so deep that we are at a loss to handle, to deal with and in some cases, even to understand. The optical guided-wave problem is just one striking example. In material sciences, we encounter with another set of problems which have not been encountered before (say, 10 or 5 years ago). For example, in diffusion processes, now we have to consider the moving atom in the medium not simply as a bare particle but rather a dressed particle surrounded by deformation potentials (just like the polaron). The physical concepts for dealing with diffusion problems are brand-new. Brand-new physical concepts, such as elementary excitations, polaritons, polarons, dressed particles, symmetry breaking, degree of order, phase transition analog etc. find a lot of applications in present-day technical sciences. The brand-new physical concepts of this kind vivid and instructive are easy to visaulize and easy to understand. The contents of the general physics courses for engineering undergradutes should be reformed and should include some of the brand-new physical concepts mentioned.

It is necessary for the graduate students of engineering, especially those of double E and material sciences, should take 2 courses namely the theoretical physics (including quantum mechanics and statistical physics) and the modern physics (including solid state physics and contemporary eptics etc.)

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THE FUNCTIONS OF PHYSICS HISTORY ON THE TEACHING OF PHYSICS

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1. Basic Situations

It has not been long since the History of Physics took the form of an optional subject in our department, and this subject has only been applied to 4 batches of graduates on a tentative basis, Hardly had the optional courses proclaimed, when the History of Physics drew the attention of the broad masses of the students. The applicants were striving for this subject. Even though the seats were not enough, there were still a good many applicants. After readjustments, the number of students was 60 in 1983, 80 in 1984, and more than 60 in 1985, with some teachers attending this class as well. After his studies, one teacher, who came from Northern Shaanxi Province Plateau, wrote an article "on the Usage of History of Physics to the Teaching at Middle Schools" published on a mamgazine. Because of this, he afterward attended a symposium of Physics Teaching in Hongzhou, Zhajiang province. He said with feelings. "This is one of my unexpected gains after I have learnt the History of Physics." This stuation is not only true with those in our college, it is also the same case with the students in Xian Junior Normal College and with those of Xiayang and Baoji Junior Normal Colleges. For example, when we gave lectures on the History of Physics to the undergraduates in these schools, the classrooms were crowded with audience. Once the notice was put up on walls, not only the graduates but the students at lower classes also came to listen, and some teachers and students of other departments attended too. Why did this subject so forcefully attract the youth of the 1980s'? Later on I made an investigation among the students and found out several causes as follows:

A) We have learnt physics and maths for years. Generally our method of study is from theory to practice and from formula to concept. It is really a hard job! Therefore, we are anxious to seek something from literature and history to balance our curriculum, to expand our area of knowledges we have learnt.

B) We have read many books on philosophy; therefore we understand the close relationship between philosophy and natural science. Our knowledge is so superficial, neither deep nor concrete, that we hope we can further explore and develop our knowledge in this field by way of learning history of physics.

C) We will always teach, and mainly teach in middle schools. With the absence of knowledge in history of Physics, it seems to me that we could hardly teach well or arouse the students' interest.

D) We have learnt much about physics, its conceptions and laws were established by scientists. But we know very little about how they speculated and under what conditions they accomplished these jobs, of which we are very ignorant. So we hope we can derive some hints from the study of history of physics, and explore and develop the intellect of the coming generations.

There may be some other causes besides those mentioned above. For instance, some students would like to take the postgraduates' course for the study of History of Physics, Natural Dialetics, and Scientific Philosophy, etc. Something like this has formed a prosperous situation in which the students are willing to attend the class of History of Physics.

II. The Arrangementof Curriculum

In order to satisfy the students' desire to seek knowledge. I basically decided the contents and teaching hours of this subject in reference to the experience of other brother colleges.

The first chapter, the preface, includes the functions, status, research menthods of the History of Physics and modes of its scientific development in 4 to 6 teaching hours.

The second chapter, a brief introduction to the history of classical Chinese Physics, includes classical universology, views on time and space, matter, and motion, along with the achievements in mechanics, thermology, acoustics, electromagnetics, optics, emphasizing analyses of the outstanding achievements of classical Chinese science and the reasons why modern science did not germinate in China, in 10 teaching hours.

The third chapter, the classical Western history of physics, includes natural philosophy of ancient Greece, the scientific achievements and incomplotements of Roman Empire and those in the Medieval Period, emphasizing the influences of natural philosophy of ancient Greece on modern sciences, in 8 teaching hours.

The fourth chapter, the birth of modern science and Universe Harmony, introduces the formation of scientific thinking and scientific method since Renaissance, namely, the contributions made by Nicolaus Copernicus, Tycho Johannes Kepler, Gililei Galileo, etc, to the formation of modern astronomy, and celestial mechanics; and the influences and functions of these achievements on modern physics, in about 5 teaching hours.

The fifth chapter, the formation and development of classical mechanics, includes the formation of classical mechanics by Issac Newton to the birth of analytical mechanics as well as the studies on atmosphere and vacuum by Evangelista Torricelli, and the development of classical acoustics, in about 6 teaching hours.

The sixth chapter, the development of thermology and moleoular physics, mainly includes thermology, thermo-dynamics, and molecular physics, in about 6 teaching hours.

The seventh chapter, the history of development of optics, includes geometric optics, physical optics, beginning from Johnnes Kepler, Issac Newton to the researches till nowadays, in about 6 teaching hours.

The eighth chapter, the development of electromagnetics, mainly introduces the researches on electricity and magnetism beginning from Benjamin Franklin to James Clerk Maxwell, Heinrich R. Hertz till now, in about 6 teaching hours.

The nineth chapter, the formation and development of modern physics, includes the discoveries of X-rays, electrons, and radioactivity; the birth and formation of quantum theory and relativity; the researches on basic particles and modern universology. The contents in this chapter are so many that we can only lecture one or two topics about them, because of the shortage of time. Among these batches of graduates, we have only given an introduction to the formation of quantum theory and modern universology, with the teaching hours being unascertained.

In view of these contents, we lecture from the outlooks on universe to universology, and from atmosphere to outer space. It seems to me that this arrangement is meaningful. It is not only concords with the development of the history but also makes the students feel profound interest in astronomy and celestial mechanics, thus bringing about good results in the process of teaching history of physics. In order to reinforce their intuitivism and imagism, we have organized the students to view video of "The Third Tide" and "The new challenger" so that we can further make them understand the functions of physics history on the whole society.

III. Major Problems in Teaching

How can we introduce such plentiful contents to students systematically in a short time? I think we should grasp several principles as follows while teaching.

A) The History of Physics is a subject of using methodology and principles of history to study the natural development of history, so this subject not only has the properties of history but also those of natural science. Therefore, if we combine these two together, we can make a conclusive retrospect and combination on physic knowledges we have learnt, and above all, we can enlighten students by methodology. We should introduce something about methodology since Aristotle's time to the students, so that they can understand how natural science has made its way from thinking into the stage of observation and experimentation, and how it has developed from the stage of experimentation into that of rational thinking. All this should be introduced by combination of some concrete scientists with their theories made by themselves, and empty talks on lectures should be avoided as possible as we can. For instance, while lecturing classical mechinics, we should pay great attention to a series of scientific methods, namely, questioning, supposition, inference, testification, conclusion, formed in the process of free falling bodies experiment made by Galileo, and introduce the important functions of idealistic expermentation on the formation of equations by James C. Maxwell and while lecturing Carlos law, we may deal with something about analogy method, As for Albert Einstein himself, he didn't seek the uniformity of contents but the harmony of forms. By means of symmetry, he succeeded in formation of both special and general theories of relativity. In a word, Through a large number of historiograpies and facts, we can make students understand the advantages of scientific methodology, which is not a negligible but an important factor which brings about the formation of scientific theories and enlighten the teachers to cultivate the students in the future by layingstress on scientific methodology.

B) We should deal with history, and should not be confined to archaeology but pay attention to the study of developments of scientific thought. Thus we can base our view on the five-time theory of physics history as a main clue, from metaphysical out-look gradually transitting to natural dialectical outlook, and introducing the formation of most representing laws and concepts. For example, the formation of Newton's Law, Coulomb's Law, Law of Energy Convertion and conservation must be analyzed to find out under what age background and on what basis of thought they were worked out. Taking Conservation Law as an example, It is unconceivable that in 1842 there could be more than 10 scientists who proposed this law, if heat engines had not been in wide use, or the inter-convertion of different natural phenomena had not been prevailing, or the unified nature outlook on philosophy had not taken the lead. When we lecture on the formation of the three laws made by kepler, we have to stress the influence of Universe Harmony Concept on him; and when we lecture on mechanical Equivalence of Heat tested by Joule, we have to stress the guidance of his teacher, John Dalton, who advocated that there exists in nature a simple law of development.

C) Physics originated from natural philosophy, so they are closely related. In history, many physicists themselves were philosophers; their scientific studies were connected with their philosophic thought at that time. Newton was a mechanic materialist and atomist, and believed in the existance of atoms, so he made brilliant achievements in mechanics. Hans Oasted had a profound understanding in philosophy and believed electricity can be converted into magnetism, so he made an epoch-making achievement. Many subjects in modern physics are even more closely related to philosophy. For instance. Alber Einstein loved philosophy since childhood, read a lot of philosophic writings, including those of Sibinlosa, Hume, Mach, from which he assimilated large quantities of nourishment. Among his great scientific achievements, many are the products of philosophy; and among his conclusions, many are aboundant of philosophic contents, especially being most prominent in Relativity. From this point of view, Albert Einstein is considered not only a great scientist but also eminent philosopher. As a matter of fact, his philosophic thought has been influencing many schools of modern Westrn philosophy considerably. For example, the appearance of Boper's Proving-pseduo philosophy was influenced on by Einstein and resulted from his influence. In order to help students understand the relationship between physics and philosophy, it is advisable to conduct them to some well-known classical works which have a representing characteristic like those "On the travelling of Celetial bodies" by "Nicolous Copenicous", "Dialogues between Two World Systems" by Galileo, "Mathematic Theories about Natural Philosophy" by Newton, "On Electric Machanics about Moving bodies" and "General Theory of Relativity for the Exploration of the Universe" by Einstein, etc. In class, we may also give a simple introduction to the basic structure and thoughts of these works, but after all, philosophy is not tantamount to physics. So its guide-line can not be over stressed. Nevertheless, it should be pointed out that every leaping forward in physics must be accompanied with the sudden changes on Cognition. The thing deserved to be pointed out is that after learning the thoughts of Einstein and Bohr, etc. We should not simply look upon physics as an applied science or a basically applied subject; it should be looked upon as one of those elementary culture subjects. If we want to raise the whole nation's scientific and cultural level, and if we want to cultivate a number of scientists like Einstein and Bohr, etc, or the scientists who are equipped with highly philosophic thoughts, it would be impossible that we did not have something of philosophy.

D) On lecturing on physics history, we have to discuss the activities of many scientists, by emphasizing their scientific reseach methods and achievemmnts. There were fine and shinning good qualities owned by these scientists who had passed away. If we introduce adequately these fine qualities to students, it would be helpful for us to cultivate patriotism, internationalism,and communism among them. For example, when we lecture on ancient Chinese history of Physics, we should elucidate the daringspirit of Wangchong who stood up to confucianism; the spirit of Shen Kou who dared to carry out reforms in defiance of nobles and was skilled in selecting good talents; the spirit of Wang Fuzhi's who was glad to be friends with the masses and good at investigation and analysis. These fine qualities are worthy of advocation. In Western countries, many scientists had very unhappy misfortunes, but they were unyielding and persisting in scientific researches, some of them like kepler, Galileo, Ohm, Miher and Madame Curie, ect are the examplars. Especially Einstein who, as a scientist of integrity, dared to struggle against German Fascism, devoted his whole life to the cause of peace. The noble fine qualities like this should be acvocated among students. One of my students, who was assigned to a remote mountain area to teach, complained of the difficult circumstances and expressed his desire to take part in a postgraduate course entrance examination. I told him that on the one hand he should be absorbed in his present work and on the other hand strive to pass the entrance exam. I gave his examples of Dalton, who had taught for a long time in high schools; and Einstein, who had been a lower clerk when he was a young man. This helped him so much that he was afterwards praised by his leadership, because he not only worked well but also led his students to carry out many scientific activities.

Generally Physics History is a highly comprehensive subject and not easy to teach. The lecturers not only should be familiar with historic facts and Philosophic inference but also should be versed in arranging materials and lecturing vividly. Hence a lot should be discussed on teaching methods and skills.

My students and I have experinced in common that Physics History is indeed one of the important components in physics education and it complements something of laws and conceptions in the course of teaching physics, and it narrates the process of forming a concept by scientists. Besides, it expounds the functions of experimentation and logic inference in the course of forming a subject, so it is beneficial for us to lead students to explore the secrets in nature and to revela the profound truth from the phenomena which we know. It is also beneficial for students to command the correct methods to carry out scientific analyses. It is important for a normal school student to command this medthod, and it will be more important for him to educate the following generations. I think this may be the main reason why this subject has been well received by students ever since its inception.

DEVELOPING THE STUDENTS' INTELLEGENCE IS THE MOST IMPORTANT TASK OF THE EXPERIMENTAL COURSE OF ELEMENTARY PHYSICS

Dong Baochang and Ye Shanshuan, Department of Physics and Chemistry
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The physics experiment is an important basic course in an engineering college. The experimental teaching in the past placed a special emphasis on training students how to master basic method of experiments, how to use elementary instruments, and how to learn foundamentary theory of experiments. But with the rapid development of science and technology and the explosive accumulation of human knowledge it is far from enough for undergraduates only to know what they are taught by their teachers. Therefore developing the students' intellegence must be put in the first place in the experimental teaching in which it is also imperative to impart basic knowledge and skill so that they are capable of consciously acquiring, applying and developing knowledge. Just as Einstein said, First priority should be always given to developing the ability to think and judge independently instead of acquiring specialized knowledge.

One question still remains to be solved: What aspects of ability and quality should be developed in the experimental teaching of elementary physics? It is worth while for each experimental teacher to study the question thoroughly. In our opinion after one year's training in the experimental course an engineering student should have the following ability and quality.

(i) a solid basis of experimental theory and basic experimental skill of experiments.

(ii) a rigorous and realistic scientific approach.

(iii) ability to think, analyze, and judge problems independently and a creative spirit.

How do we achieve the above aims? In the following I will introduce some of the recent years' work that has been done in our department.

I. First of all, we have established a stable team of teachers who are rigorous and realistic and fond of the experimental teaching. We have also made a set of stringent rules and regulations of the laboratory and set concrete demands in the experimental teaching. The textbook and instruments for experiments have been improving and perfecting all the time. In this way a good environment for developing the students' intellegence have been created.

For a long time in the past the experimental teaching was taken in turn by teachers who give lectures in the classroom. Usually they thought they only worked there temporarily so they did not do much in studying the teaching method. Under these conditions it is hard to carry out the reforming measures of the teaching method and guarantee the quality of

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Not only have the teachers set an example for students through their own serious attitude toward the experimental teaching but also they have made rigid requirements in students' preparation, operation, data processing, experimental report and grading. Much emphasis have been given to training and developing the students' serious scientific approach and practical and realistic style of work in our department.

II. We have used the teaching method of "step by step" in accordance with the students' actual conditions.

At the begining of 1985 we made an investigation on the real standard of experimental physics among undergraduates enrolled in September, 1984. The result showed that their experimental skill was poor in spite of the fact that they got high scores in the entrance examinations. Most of them did very few physical experiments in middle schools. Nearlyhalf of them did not operate by their hands and even did not see with their eyes some of the most basic instruments such as balances, vernier calipers, stop watches, and bridges etc. In view of this situation we have used the teaching method of "step by step". By 'step by step' we mean that the course is divided into four stages: each stage has its own concrete requirements and a higher stage has more difficult requirements than a lower one. All of the students are able to acquire much higher experimental skill and more independent ability to work after one year's training. Our concrete measures will be introduced in the following.

(i) The first step is preliminary stage in which the introduction of the experiment and the most basic experiments of mechanics and heat are introduced skill can be led to a correct approach. Developing the students' scientific approach is placed before anything else in this stage. The experimental textbook is written in detail. Furthermore the teachers give full instruction to students in preparation, operation, experimental report and data processing etc. so that they do their experiments both seriously and well. Through the first stage's training students can establish gradually the faith and interest in doing experiments well. The proportion is 25% of this stage's experiments to the total experiments.

(ii) The second step is the enhancing stage in which the students' ability to do experiments independently is to be fostered gradually. The experiments in this stage are mainly some of the basic experiments of electricity such as the experiments on potentiometers, bridges, oscillographs etc. in which students are asked to connect and check electric circuits and fix some of simple breakdown under the less detailed instruction of their teachers. The contents of the experiments are, in essence, divided into two groups; the first one is what each student has to do and the second one is what they may do or not by their own will. The textbook on the experiments is written briefly. The students are required to write experimental reports in their own words other than the ones in the textbook. At the same time the item of experimental discussion is added on the report so that students can analyze problems encounted in experiments and propose their own views on them. The proportion is 35% of the experiments in this stage to the total experiments.

(iii) The third step is the stage for students to do experiments independently. Students are asked todo experiments independently such as spectral analysis, adjustment of spectromenter etc. On the basis of the experiments they have done and through to the fundamental requirements in the textbook.

Gernally speaking each student has a piece of apparatus in such an experiment. The textbook is written so briefly that in it there are only some fundamental requirements and several problems for thinking. The teachers do not lecture systematically but give students some advice of principles and solve problems proposed by them. The experiments are scheduled to take three lesson periods: In the first period students make preparation and in the second and third periods they do operations. In preparation students read the textbook, instruction of instruments and other reference materials in face of the apparatus. They are also asked to make out an outline for operation and draw up a list on which experimental data are taken down. The proportion is 25% of the experiments in this stage to the total experiments.

(iv) In the fourth step there are mainly more difficult and comprehensive experiments such as the Milliken's experiment of oil drops, measuring tungsten escape work and Young's modulus of metals at high tempretures etc. Students may select by their own will one or two experiments which are offered. Another alternative way is that students design experiments on their own according to the teachers' requirements and in combination with the examination of the course. Such an experiment is gernerally scheduled to take two weeks. In the first week students make preparation or design for experiments and in the second one they conduct experiments in the laboratary. They are allowed to cooperate with each other and even discuss with their teachers about experiments. But the most important thing is that each student must bring his or her subjective activity into full play so that their comprehensive thinking ability and creative spirit can be trained and strengthened. This kind of experiments has been very popular with students since they were first offered in 1985. Unfortunately these experiments are small in number and their proportion to the total experiments is only 15%.

As for the examination of the course we give the examination to the students at the end of each semester and there are two examinations in total. One is intended to test the basic theory, method and principle of experiments and the other, to test the operation and design of experiments. The result of the examinations has proved that after one year's training the students' experimental skill and ability of independent work are much improved.

III. To further stimulate the students' consciousness and interest of study and especially to develop the latent intellegence of some prominent students who are interested in physical experiments, we hold a variety of extracurricular activities.

(i) Establish all kinds of interest groups.

Young people are full of vigour and have a strong thirst for knowledge They take much interest in fresh things. Einstein said, Interest is the best teacher to acquire knowledge.

According to students' interest we have established the students' union of physics, the interest group of astronomy and the instrument-making group etc. Students play the most important role and give free rein to their subjective activity in the interest groups.. They have learned a great deal from visiting, making instruments, and listening to lectures etc. The extracurricular activities have created many capable students.

(ii) Open laboratary to students

To provide students with more opportunities of experimental operation we open one laboratary specially for students to use in the extracurricular activities. The experiments opened are roughly divided into the following three groups. The first group is nearly the same as the class-grouping experiments so that they can be used for preparation or revision. In fact they are also be used by the students who don't fulfill the experiment in class. The second group is more diffciult than the first one, e.g. experiments of mechanics and heat and some physical experiments of intermediate level for students who are specialized in physics. group of experiments is especially prepared for outstanding studn who have interest in physical experiments. Students are permitted either to hand in their reprots or not. The last group is the experiments of more or less research value. These situations may be encountered when undergraduates and postgraduates make their design or write their thesis for graduation, e.g. measuring index of refraction of liquid, measuring rotational inertial of small and middle rotation axes in a recorder. Under these conditions students make design for experiments and conduct the experiments completely on their own.

Opening laboratary has produced postive effects on developing students' intellegence. It is very popurlar with students. They said, "Opening laboratary is our good news."

(iii) Hold all sorts of lectures on experiments

Experiments need a lot of creative thinking, for instance, in making instruments, in improving experimental methods and in analyzing experimental results.

The experimental teachers in our department give lectures to students on their own experience in developing instruments such as how to apply theory to practice, how to make design for experiments, how to solve problems and how to improve quality of instruments etc. The knowledge is absolutely neccessary for a future engineer but it is difficult for students to learn it from books. Students are very fond of such lectures. They said they learnt a lot of things from them.

Under the positive influence by their teachers students themselves also write specialzed reports about some experiments, e.g. "Several methods of measuring gravitational accelation and their comparison". "A proposed on improving instruments of measuring heat conductivity of metals", "The fixation of common breakdowns in oscillograph" etc. They also hold symposia to exchange their experince in doing experiments. These activities both enliven the academic atomosphere and train the students' ability to express themselves.

A famous French pedagogist said. "A good teacher teaches people how to discover truth while a bad teacher only passes on truth to people". We have emphsized developing students' intellegence and made great progress in the recent years' teaching of physical experiments. But what we have done is only the beginning and there is a lot of work to do in how to rasse students' level of doing experiments and strengthen their creative ability.

REMARKS ON TWO-DIMENSIONAL TEACHING AND MULTIDIMENSIONAL EXAMINATION

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Problems of fostering the student's ability in college physics will be discussed in this article on the basis of multidimensional thinking. Two aspects are presented: medthods of teaching and means of examination.

1. Two-dimensional teaching in college physics

The most important tasks of physics teacher are to pay special attention to the development of the students' abilities as well as helping students master physics thoroughly and systematically. However, there have existed all along three widespread problems in the field of physics teaching in colleges and universities. First, most students think the contents and chapters of physics texts innumerable and disorderd, difficult to learn and not easy to put into practice. Second, they think that there are too many repetitions of the contents between college and high school, so they have less interest in their studies. Third, many teachers consider the students simply as "vessels," using "forced-feeding" method of teaching.

From this situation, the concept of two-dimensional teaching has emerged. It consists of both horizontal and vertical teaching. Its distinguishing feature is a comprehensive balance between these two aspects. It is a weakness that most parts of mechanics are repeated in both high schools and colleges. We grasp this point and turn the disadvantage into an advantage. We use the thoughts of two-dimensional teaching and reorganize the teaching materials, summing up the content on mechanics into two chapters and four problems (basic motion, resultant motion; basic law, derived law). For the parts that cannot be summed up into those two chapters, we treat as lectures on special topics. Also we select typical problems and analyse them in a coherent and unified way, then ask the students to solve the problems using different methods.

In the school year of 1981/82, we made the first teaching experiment in the major of mechanical manufacturing for Classes 8101 and 8102. We broke free from conventions and considered three motions—the particle's rectilinear motion, the axial turning and the circular motion of the rigid body—as the basic motions and taught them intensively. It aroused students' great interest and gained excellent results. We finished within 21 hours the tasks prescribed in the old teaching syllabus for 28 hours and thus raised the teaching efficiency by 25 per cent.

Chart I

marks	below 59	60-69	70-79	80-89	90-99	100	total
number of students	3	18	27	16	8	1	73
per cent	4.1%	24.6%	36.9%	21.9%	10.9%		100%

Chart I: Results of Classes 8101 and 8102 Examination

We used two-dimensional teaching for Classes 8301 and 8302 in mechanical manufacturing (school year 1983/84). We had a survey to check on the teaching efficiency in mechanics and electromagnetic field. We can see from Chart II that the two-dimensional teaching method is affirmed greatly by the students.

Chary II

Item	Mechanics				Electromagnetic Field			
Rating	good	fair	poor	total	good	fair	poor	total
Number of Students	41	26	1	68	62	9	1	72
Per Cent	60.3%	38.2%	1.5%	100%	86%	12.6%	1.4%	100%

Chart II: Student Survey on Two-dimensional Teaching

Since the two-dimensional teaching method breaks through the traditional teaching system, organized the teaching materials reasonably and increases the teaching density, the teaching efficiency of the three parts of the contents were raised by 25%, 14.3% and 10.3% respectively. Especially, two-dimensional teaching method avoids the forced-feeding method and reflects the strength of the elicitation method of teaching. So the students are free from the passive role. It is of great help in improving the wisdom of the students.

In order to adapt to the needs of two-dimensional teaching method, we compiled three volumes of teaching materials completely different from the traditional teaching materials. Our guiding principle is to collect together concepts which are similar, principles which are close and forms which are the same. After trying out, we found satisfactory results.

2. The multidimensional examination in physics

A. The leading thoughts and components of the multidimensional examination

The multidimensional examination was developed through teaching practice. In order to explain it thoroughly, let us first objectively analyse the written examination:

Written examination (including the oral test) is the test method passed down from the past. It has its own advantages, but it also has these disadvantages:

(1) Written examinations severely fetter the students' thinking. The students have to mechanically recite the teaching materials and notes in order to deal with the examination which determines their final marks. This makes the students narrow their thinking and fall short in learning, and it is helpful neither in fostering the abilities of the students nor in checking their abilities overall.

(2) Students who have independent ideas and habits of assiduous study between examination frequently don't get good marks. This shows that written examinations cannot reflect a student's real level and, thus, they their limitations.

(3) Written examinations are just a method of testing, and cannot be combined with the fostering of abilities. So exclusive use of written examinations would not meet the requirements of the developing modern world.

In order to overcome these disadvantages, we have experiment with the multidimensional examination:

(1) Combine several kinds of examination methods to reflect the student's real level and ability as completely, truly and accurately as possible, and to free the students from having only a single examination paper.

(2) Make the award of degrees dependent on the students' coursework, thus arousing fully the learning initative of the students and promoting their interest in studying.

(3) Make the examination itself to be a means of fostering the students' abilities.

(4) Use the results of other examinations, as well as the final examination, in determining the students' marks.

We experimented with the multidimensional examination in the major of mechanical manufacturing for Classes 8401, 8402 and 8403 in the 1984/85 school year. The contents were as follows:

(1) We asked the students as an aspect of examination to write a thesis. The purpose of this is: (a) to lead and encourage students to observe the society, nature, industrial production and life; (b) to explain some phenomenon using the knowledge within their power; (c) to calculate or state some problems; (d) to foster the spirits of forging ahead, endeavouring to gain professional proficiency, and constantly bringing forth new ideas; and (e) to foster their abilities of observation, analysis, abstraction, summarization and expression.

(2) We incorporated the assignments into the course mark. This was developed through teacing practice. We observed a general statistical principle: classes which finished their assignments well tended to have higher marks and a better attitude toward the course, and vice versa. (see Chart III)

Chart III

Class	Rate of Finishing assignment	Average Final Marks	Attitude	Class	Rate of Finishing assignment	Average Final Marks	Attitude
7901	60%	82.5	Average	8101	54%	69.3	Average
7902	64%	84.5	Good	8102	61%	70.7	Good
80day student	45%	62.0	Poor	8301	73%	66.8	Average
8001	56%	69.9	Average	8302	82%	71.7	Good
8002	72%	73.7	Good	8304	64%	80.8	Good
				8305	41%	69.7	Average

Chart III: Statistics about the Relations Between the Rate of Finishing Assignments and Final Marks

It is important for the students to finish certain quantities of assignments independently, This is basic training to help students foster the ability of analysing and solving problems, and to encourage them forward rigorous scholarship. The results of the assignments sould be recorded into the students' school report. Of course, we should also take measures to prevent students from plagiarizing.

(3) Written examinations: Passing on knowledge and fostering ability supplement each other. For the teacher to pass on knowledge is still one of the important respomsibilities. The key point is how to combine these two aspects. So we continue to retain written examinations as one component in the multi-dimensional examination. We accept two forms for written examination: one of them is the final written examination, for other examinations we count one mark for each problem.

B. The changes brought about by the multidimensional examination

We had two multidimensional examinations in 1985 and they brought about great changes among the students (see Chart IV)

Chart IV

Class	Rate of Finishing assignment	Marks for Assignments	Rate of Finishing Theses	Marks for Theses	Marks for other Examinations	Marks for Final Exams	Total Marks
First Term							
8401	86.7%	26.5	90.0%	12.7		36.2	75.4
8402	96.7%	27.8	96.7%	13.5		34.7	76.0
8403	100%	28.8	93.3%	13.6		34.7	77.1
Average	94.4%	27.7	93.3%	13.3		35.1	76.1
Second Term							
8401	96.7%	19.1	96.7%	14.5	7.9	35.3	76.8
8402	93.1%	17.8	82.8%	14.6	7.6	37.7	77.7
8403	100%	19.1	90.0%	15.0	7.7	38.0	79.8
Average	96.6%	18.7	89.9%	14.7	7.7	37.0	78.1

Chart IV: Results of the Multidimensional Examination

(1) The titles of the theses were worked out mainly by the students themselves with some help from the teachers. Those who could choose for themselves brought their initiative into full play, while the titles given by the teachers helped the students who didn't know what subjects to choose. This can encourage more students to write the thesis. From Chart IV we see the high rate of thesis completation. We received in two school terms 172 theses which are in different styles and on different themes. Although the effects produced from this are not so clearly evident as that of written examinations, they would have a profound influence on developing the students' thinking and on their scientific research after graduating from school.

(2) The thesis examination developed the depth and breadth of the students' studies. It could advance students from simply reciting the teaching materials and notes to extensively reading books, magazines and much more information. According to rough estimate, the students read about 500 reference books within two school terms. One of the students said, "The multidimensional examination can free our thinking and help us use our brains. It is not enough for us to write a thesis just according to the teaching materials and notes. We have to read more relevant books."

(3) We can see from Chart IV that the marks of the theses are rather low. This was done conciously by us. In order to encourage students to write the thesis, we also took some special measures: when we experimented with this the first time, we printed two theses of excellence. Seven of

the students who wrote an excellent thesis were exempted from the written examination. This gave the students a great shock. Thus though there were less teaching hours in the second term, the students were enthusiastic about writing the thesis.

(4) Both the quality and the quantity of the assignments finished by the students are better than ever before, but we detected cases of plagiarism. If it is not prevented, there is no sense in doing the assignments. Thus, we declared to the students any cases of plagiarism would be regarded as irregularities in the examination. At the very beginning, we punished two such students, afterward, there was no plagiarizary.

(5) In order to help students finish their assignments independently, we encourage the students to have discussions. each other first, then after getting a thorough understanding, to finish the assignments themselves. This broke the passive situation of mechanical memorizing and cudgelling their brains, thus a new situation of warm discussions, exchanging views, open thinking and deep understanding emerged. This also raised the students' general attitude forward their studies.

(6) Though written examinations constitute a larger proportion of the term marks, since it is not a conclusive factor, the students' thinking is more active. One of them said, "The multidimensional examination liberates us from a single examination paper and wipes out our anxiety, so the effects of our studies are greatly improved." Experience shows that after using the multidimensional examination, the marks of all classes remained above middle-upper levels. In a competition, students from these three classes won the first-place prize, two second-place prize and on third-place prize. Furthermore, two of the classes placed in the top five among the fourteen classes entering the competition. Yet, the entrance examination marks of these students were lower than other classes.

(7) The relative weight of the multidimensional examination's three components can be controlled flexibly. These weights in the two terms were 2: 3: 5 and 2: 2 : 6 respectively (see Chart IV).

Traditional educational thought always treats the students as receivers but from the standpoint of the science of teaching, this is single-mode thinking. Recently, people have seen its one-sideness and closedness. However, many teachers still just recognize the receiving side of their students and ignore their creative side, or they only appraise the students according to book knowledge and don't use other standards. Obvioursly, if the teachers don't change their one-sided way of thinking, the higher education will not experience breakthrough required to meet the need of the coming era. Basically, the purpose of this article is to develop a new multidimensional teaching system by combining teaching methods, systems of teaching materials and methods of examination to overcome the drawbacks in methods of current higher education. Our educational experiment has made some progress, but it still needs to be perfected and enriched, so we hope that our colleagues will enlighten us with their instructions.

Appendix

Students' Theses, Selected Titles

1. Tentative Research on the Problem that the Coefficient of Sliding Friction Is Less Than the Coefficient of Static Friction for Hard Objects
2. The exchange of Energy Between Floors in a Building
3. The Shooting Process of Semi-automatic Rifles
4. Mechanics in Playing Table Tennis
5. Thoughts coming from Playing on a Swing
6. The Appropriate Choice of a Reference System
7. The Coherence of Cummlative Effects of Force in Time and Space
8. Remarks on the Friction Holding a Bottle in the Hand
9. Two Views about the Acceleration of Gravity
10. A Specious Problem
11. Why aren't you Walking straight?
12. Can Electron in the Photoelectric effect Absorb More Than One Photon and Escape Away?
13. Calculation of the Relation Between Mass and Energy and Its Significance
14. An Analysis and Comparison of Einstein's and Newton's Views on Time and Space
15. The Influence of the Length of Wave Train on Wave Interference
16. The Achievements and Deficiency of the Bohr Hydrogen Atom Theory
17. Physical Significance of Optical Path and Optical Path Difference
18. My View about Power Electromotance
19. The Application of the Presentation in Physics
20. From Planck's Quantum Hypothesis to Einstein's Formula of Photoelectric Effect.

REMARKS ON THE RESEARCH OF EXPERIMENTAL APPARATUS FROM THE EVOLUTION OF THE FRANCK-HERTZ EXPERIMENT

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The Franck-Hertz Experiment (abbreviated to F-H Exp below) which demonstrates the existence of energy levels of atoms by governing the impact of an electron upon an atom is one of the crucial experiments in modern physics. Since the designers of the experiment, James Franck and Gustav Hertz succeeded in proving the Bohr's hypotheses of 1913 that for every atom there are an infinite number of discrete stationary states and the radiations are always concerned with the transitions of the atom from one stationary state to another, they were awarded the physics Nobel Prize for the year 1925.

It is helpful for students to understand the structure and the concept of energy level of an atom by introducing F-H Exp to Physics labs in universities because of its ingenious verification of the existence of energy levels in atoms and its distinct reveltion of the inner pictures of atoms. Therefore, though more than seventy years have passed since F-H Exp was published in 1914, it is still performed as a classical experiment by students in physics labs of many universities except for the new fieds developed by the collision between particles. It can be seen how prefound the significance of F-H Exp is.

The purpose of the paper is to review the evolution of F-H Exp briefly according to some materials concerned and then give several points of remarks on the research of experimental apparatus.

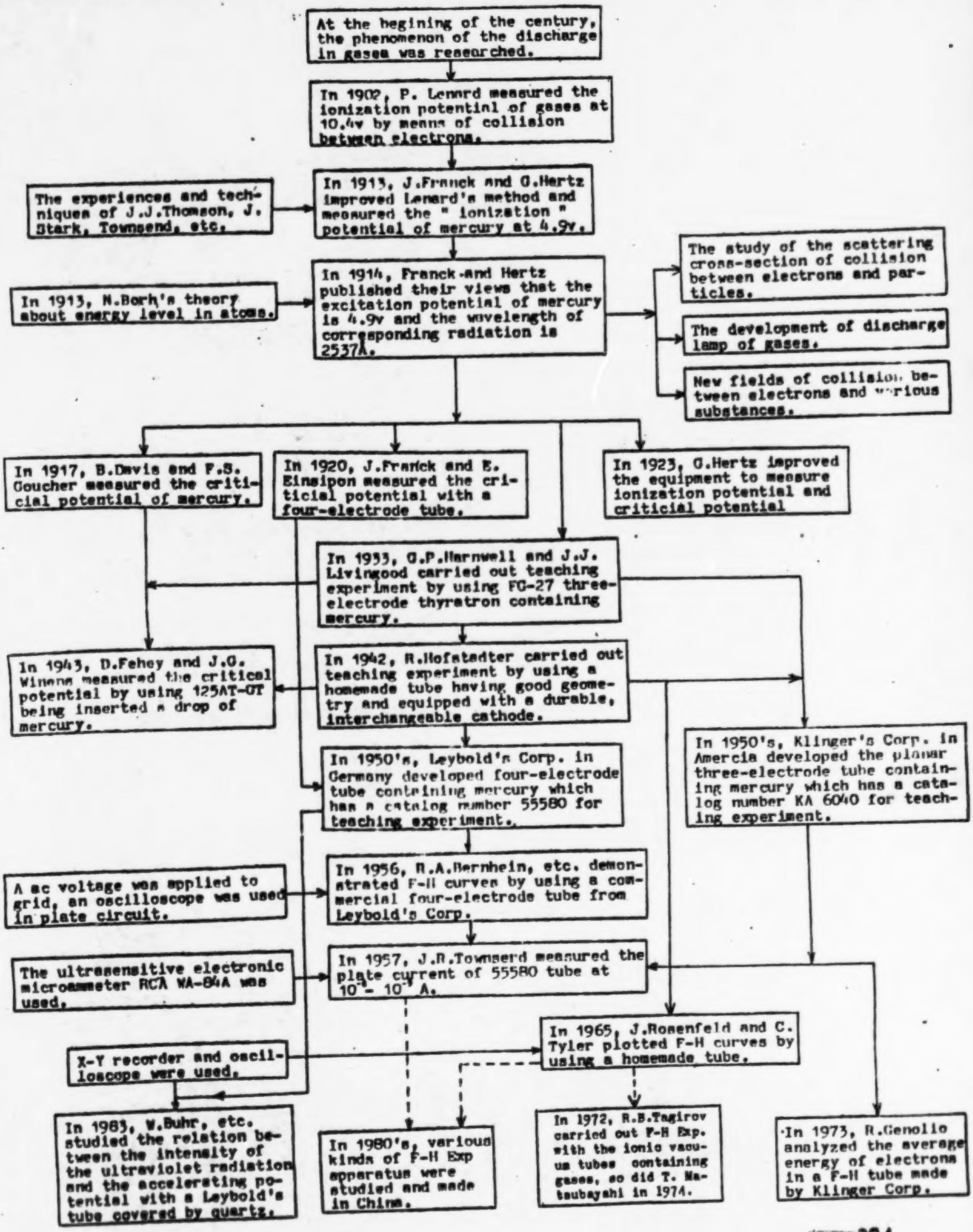
A CONCISE INTRODUCTION TO THE EVOLUTION OF F-H EXP

As we know from some reference materials, F-H Exp has been developed mainly as follows: (Next page)

THE REQUIREMENT OF STUDYING AND INHERITING AS WELL AS BOLDLY REFINING THE FORMER THINGS FOR THE RESEARCH ON EXPERIMENTAL APPARATUS

Looking back on the evolution of F-H Exp, we can take the work of Franck and Hertz as an example.

Professor C.W.OSEEN, a member of the Nobel Committee pointed out in 1925: "Franck and Hertz have opened up a new chapter in physics." "This should not be interpreted as meaning that Franck and Hertz were the first to ask what happens when an electron collides with an atom or a molecule, or that they were the originators of the general method which paved the way for their discoveries and which consists of the study of the passage of a stream of electrons through a gas. The pioneer in this field is Lenard." J.Franck himself also said: "We had experiences and techniques to support us, which men like J.J.Thomson, Stark, Townsend and in particular, however, Lenard, had created."


At the begining of the century, the phenomenon of the discharge in gases was researched.
In 1902, P. Lenard measured the ionization potential of gases at 10.4v by means of collision between electrons.
The experiences and techniques of J.J.Thomson, J. Stark, Townsend, etc.
In 1913, J.Franck and G.Hertz improved Lenard's method and measured the " ionization " potential of mercury at 4.9v.
In 1913, N.Borh's theory about energy level in atoms.
In 1914, Franck and Hertz published their views that the excitation potential of mercury is 4.9v and the wavelength of corresponding radiation is 2537Å.
The study of the scattering cross-section of collision between electrons and particles.
The development of discharge lamp of gases.
New fields of collision between electrons and various substances.
In 1917, B.Davis and F.S. Goucher measured the criticial potential of mercury.
In 1920, J.Franck and E. Einsipon measured the critical potential with a four-electrode tube.
In 1923, G.Hertz improved the equipment to measure ionization potential and criticial potential
In 1933, G.P.Harnwell and J.J. Livingood carried out teaching experiment by using FG-27 three-electrode thyratron containing mercury.
In 1943, D.Fehey and J.G. Winens measured the critical potential by using 125AT-GT being inserted a drop of mercury.
In 1942, R.Hofstadter carried out teaching experiment by using a homemade tube having good geometry and equipped with a durable, interchangeable cathode.
In 1950's, Leybold's Corp. in Germany developed four-electrode tube containing mercury which has a catalog number 55580 for teaching experiment.
In 1950's, Klinger's Corp. in Amercia developed the planar three-electrode tube containing mercury which has a catalog number KA 6040 for teaching experiment.
A ac voltage was applied to grid, an oscilloscope was used in plate circuit.
In 1956, R.A.Bernhein, etc. demonstrated F-H curves by using a commercial four-electrode tube from Leybold's Corp.
The ultrasensitive electronic microammeter RCA WA-84A was used.
In 1957, J.R.Townserd measured the plate current of 55580 tube at $10^{[illegible]} - 10^{[illegible]}$ A.
In 1965, J.Rosenfeld and C. Tyler plotted F-H curves by using a homemade tube.
X-Y recorder and oscilloscope were used.
In 1983, W.Buhr, etc. studied the relation between the intensity of the ultraviolet radiation and the accelerating potential with a Leybold's tube covered by quartz.
In 1980's, various kinds of F-H Exp apparatus were studied and made in China.
In 1972, R.B.Tagirov carried out F-H Exp. with the ionic vacuum tubes containing gases, so did T. Matsubayshi in 1974.
In 1973, R.Genolio analyzed the average energy of electrons in a F-H tube made by Klinger Corp.

Although Franck and Hertz had learned much from these pioneers, their success is that they dare to doubt and refine what the pioneers created instead of resting content with understanding and using the previous knowledges only.

At the begining of this century, a series of measurement were taken to determine the ionization potentials of various gases becuase they were particularly significant to the research on the phenomenon of gases' discharge. Lenard always got 10.5V or so ionization potentials when he measused various gases by meas of collision with electrons, whereas others obtained different results from the same'samples with different methods. Which is true? Lecturer Franck and Assistant Hertz at the University of Berlin, who were only thirty-one and twenty-six years old at that time, noted these differences and thought of the question carefully. They didn't accept Lenard's method and conclusion without a doubt. Making a critical study and improving the operating conditions, they repeated Lenard's experiment and found at last that the ionisation potentials varied with different gases. So that's how it is! The reason for Lenard's measuring results is that he produced a vacuum with a mercurial pump, keeping presure in the tube at 10^{-2} mm Hg, and thus contaminted the sample gases with mercurial vapor. 10.4V is the ionization potential of mercury! From the above mentioned, we ought to draw a lesson that the condition in a scientific experiment is extremely important.

Franck and Hertz found, furthermore, that in the previous experiments for measuring ionization potentials, people paid no attention to what changes the electrons took place while they were observing the atoms to be ionized by collision with electrons. In order to know the changes of electrons, Franck and Hertz refined the structure of Lenard's tube as Figure 1 and Figure 2:

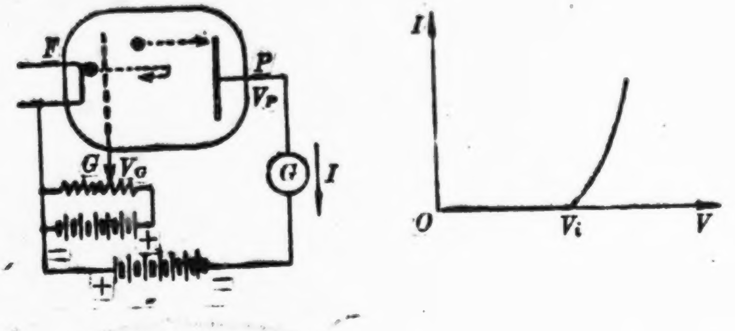


Figure 1.
Result of Lenard
Experiment and
his tube & curve

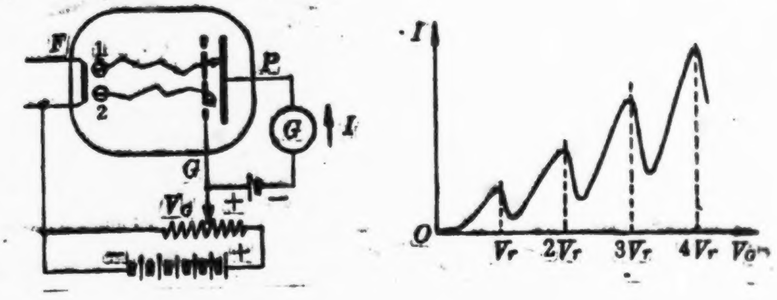


Figure 2.
Result of Franck-
Hertz Experiment
and Their tube &
curve

1) To increase the distance between filament F and grid G from 5 mm to 4 cm;

2) decrease the distance between grid G and P from 2.5 cm to 1-2 mm. Thus, the space where electrons collided with atoms was altered from PG to GF. Then they diminished the voltage between G and P from more than 10V (adjustable) to less than 4V (stationary) and connected Positive pole to grid G, keeping plate P positiver than cathod. The improvement insured electrons to fall on plate P and the changes of electrons were measured by detecting the plate current. The results were very interesting and attractive. They discovered the truth.

We can conclude that only keeping an open mind and taking the problems in his work into account from every angle can one succeed.

THE NECESSITY OF COMBINING PRACTICE WITH THEORY CLOSELY

After getting a regular undulate curve of plate current, Franck and Hertz tried to explain it with the view of ionisation potential. They determined the threshold voltage of mercury V_r at 4.9V, but many other scientists measured the ionization potential of mercury at 10.4V. They therefore puzzled over why there existed such large different voltages. Having consulted the Bohr's hypotheses, they were inspired by the theory. If the frequency of the radiation emitted or absorbed respectively during a transition is given by the equation

$$h\nu_r = E_2 - E_1 \text{ (Figure 3)},$$

and if eV_r is the energy which enables an atom to transit from ground state E_1 to excited state E_2 from

$$h\nu_r = E_2 - E_1 = eV_r$$

one can know that threshold voltage V_r corresponds to a radiation whose wavelength λ_r is hc/eV_r. From the theory, Franck and Hertz were aware that the ultraviolet light 2537 Å in the mercurial spectra needed 4.86V as excitation potential, which was almost in accord with their measuring value.

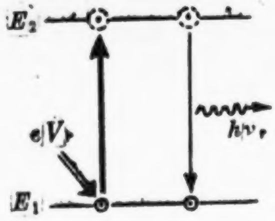


Figure 3. An excited radiation of an atom

When Franck and Hertz realized the threshold voltage 4.9V most probably was the excitation potential, they redesigned the tube by using quartz glass as tube's crust and detected the radiation with a ultraviolet spectrograph. They discovered successfully that not any radiation occured when the accelerating voltage was below 4.9V, whereas when the accelerating voltage was over 4.9V, just as expected, the mercurial vapor emitted a radiation, a solitary ultraviolet light with 2537 Å wavelength!

Thus, the Bohr's hypotheses are no longer mere hypotheses but experimentally proved facts. From the establishement of Bohr's hypotheses to the success of F-H Exp, we can see clearly that theory results from experiment and guides to a further experiment which will produce new theory.

CIVING HEED TO THE INTRODUCTION OF NEW TECHNOLOGIES AND NEW METHODS

Besides the improvement of the tube of F-H Exp, the equipment for detecting plate current also evolved continuously with the development of science and technology. Begining with the earliest quadrantal static meter and sensitive galvanomenter, the indicators with amplifiers consisting of electrom tubes, transistors or even the integrated circuits have been made one after another by now.

For displaying the results, oscilloscopes and X-Y recorders are used to show and record the curves instead of being done so by hand. Recently microcomputers are more and more interfaced with the experimental apparatus for collecting and analysing the data automatically.

With reference to heating tubes (except for the tubes containing gases), Franck and Hertz had to use a Bunsen burner because of the restriction of the conditions, but the people today are using universally the electric ovens. Furthermore, an automatical controller of temperature with a couple-metal flake is in place of the self-coupling transformer to govern the input of filament. Some precise controllers can maintain the given temperature within ±0.5°C.

The introduction of new technologies and new methods to scientific experiments can enhance the precision and accuracy of the results, reveal the details which couldn't be measured in the past and thus prompt the experiments to a new stage.

PROCEEDING THE RESEARCH ON EXPERIMENTAL APPARATUS FROM THE OBJECTIVE REALITIES

After F-H Exp was published, many people were interested in it. They Perfoemed F-H Exp under different conditions with different purposes.

From the book «Experimental Atomic Physics» written by G.P.Harnwell of Princeton University and J.J.Livingood of Washington University, we know they used a FG-27 tube (a three-electrode thyratron) instead of Franck and Hertz's tube to make teaching experiment. FG-27 tube can be available commercially, its interenal structure is the same as that of Franck and Hertz's tube, and it is also inserted with mercurial vapor. Maybe that is the reason for their introducing FG-27 tube to teaching experiment first.

The result of F-H Exp with FG-27 tube is shown in Figure 4. Though the curve is less perfect than that of original apparatus (shown in Fig. 2), it is still satisfactory for teaching purpose because the average excitation potential is 4.84V which is only 0.4% less than the standard value.

G.P.Harnwell and J.J.Livingood are the first to simplify a scientific experiment into teaching experiment. Many people are enlightened by them. Some people tried to make F-H tube by themselves and carried out F-H Exp successfully by using the coaxial communication tube or ionized vacuum tube which were inserted with mercury or gases. It is worth mentioning C.E.Tyler of Wasington University who designed a very simple F-H tube and constructed an oven with brick and heating wire. The cost of materials is only about US $1.00 per tube. The curve of his experiment is shown in Figure 5. Though the curve is not so perfect as those produced by the tube made by Leybold's Corp. of Germany and Klinger's Corp. of Americal (shown in Figure 6 and Figure 7), it can solve practical problems. Just as Tyler said: "Therefore, it now seems possible to incorporate the construction of the tube as well as the performance of the Franck-Hertz experiment into the usual undergraduate experimental physics program."

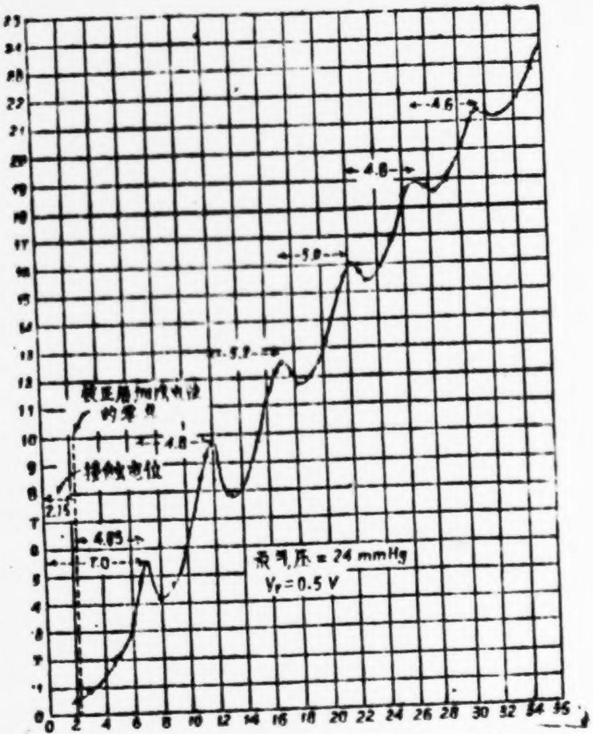


Figure 4. The curve measured by using FG-27 tube containing mercury

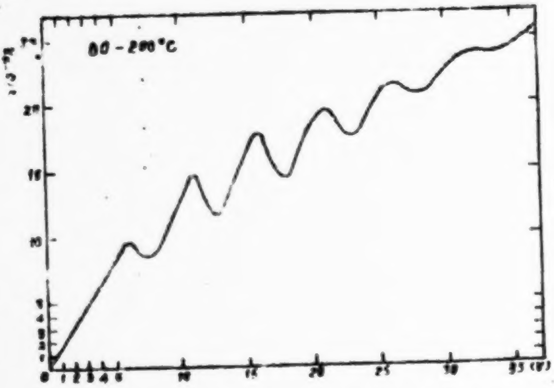


Figure 5. The curve of F-H Exp by using Tyler's tube

Nowadays, F-H Exp for teaching purpose has developed towards both lower and higher aspects. On one hand, it was performed by the students of lower grades in universities or the students who don't major in physics, or even the students in high schools to popularize the concept of energy level in atoms. Some manufacturers are managing to simplify the equipment of F-H Exp in order to make a low cost apparatus for teaching experiment and demonstration. On the other hand, however, other manufacturers such as Leybold's Corp., etc., are trying to refine the equipment of F-H Exp further in order to research the relation between the intensity of far-ultraviolet and accelerating potential by cooperating the development of this experiment.

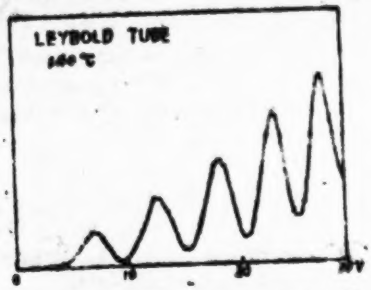


Figure 6. The curve of
F-H Exp by Leybold's
Corp. tube 55580

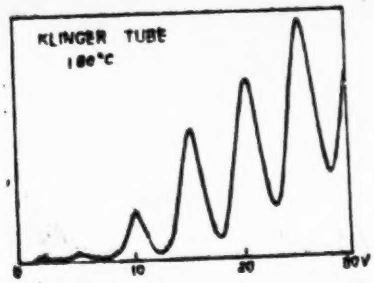


Figure 7. The curve of
F-H Exp by Klinger's
Corp. tube KA6040

It China, the research and manufacture of F-H Exp for teaching purpose was started about in 1980. Through five year's endeavor by Chinese people, various kinds of F-H Exp apparatus have been made.in Science & Technique University of China, Liaoning Normal University, Nanjing Institute of Technology, Fudan University. Recently, Fudan University and Liaoning Normal University even worked out the equipment which can detect the radiations emitting from higher energy levels. In addition, many advanced experimental equipments in other fields are springing up. It is believed that with the development of our national economy and the increasing emphasis on the cause of education by the state, the level of the research on experimental apparatus in China will surely be raised in the near future.

As we know from some reference materials, F-H Exp apparatus have been made in corporation and factory as follows:

1. Mercury-filled triode model
   1) Klinger's corp. (U.S.A.)
   2) Phywe's Corp. (Germany)
   3) Neva's Corp. (Germany)
   4) Nanjing Institute of Technology (P.R.C.)
2. Mercury-filled four-electrode tube model
   1) Leybold's Corp. (Germany)
   2) Shimazu's Corp. (Japan)
   3) Uchida's Corp. (Japan)
   4) Science & Technique University of China (P.R.C)
   5) Fudan University (P.R.C.)

3.. Gas-filled four-electrode tube model
   1) Uchida's Corp. (Japan)
   2) Liaoning Normal University (P.R.C.)

4. Gas - filled triode (Pirrin tube) model
   1) Leybold's Corp. (Germany)
   2) Shenyang Teaching Instrument Factory (P.R.C.)

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13) 松林勉，日本物理教育学会誌 22 (1974) 89

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THE MEASUREMENT AND EVALUATION OF PHYSICS TEACHING QUALITY IN HIGH SCHOOL

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1. Recognition of the measurement and evaluation of the course teaching

To-day, to deal with the measurement and evaluation in the course teaching quality is not only different from the old time to the present day so called general examination, but also different from educational test which is popular in the beginning of this century. The measurement and evaluation of the quality of course teaching is to serve the purpose of course teaching, but the purpose of teaching will be influenced by the development of the society. In the history of education, during quite a long period, the purpose of course teching is limited to impart knowledge. The essential requirement of the teaching quality is: the students are able to correctly remember the knowledge given by the teachers, therefore the use of general method of examination to test the teaching quality had never been objected. But by the beginning of this century, under the influence of the movement of intelligence test, the educational test also becomes flourishing. The appearence and the way of giving grades of this kind of test get standardized, there fore the scientific spirit and accuracy get comparatively more remarkable. But, talking about the contents, it still tends to consider the remembrance knowledge. Although, some schools also test about intelligence, yet the purpose is to choose students suitable for education; but to—day, the educational requirement of the society is to let all children get maximum development and pay attention to educating creative talented people. Now we must shift the purpose of measurement and evaluation of education from choosing children suitable for education, to choosing education suitable for all children. In the mid - thirties of this century, some educators and psychologists, in adjuoating and modifying educational test at the same time begin to advance the experimental investigation of evaluation of education. In the way of teaching, at present, people incline to emphasize the quality of teaching academic level of teachers, manner of teaching, contents of teaching, method of teaching and conditions pvovided for teaching and the quality of learning (the development of moral education, intellectural education and physical culture of the students), to evaluate the quality in the course of teaching. We think at present, this is general view for the measurement and evaluation of the quality of course teaching. Because of the limited space, this paper only gives from the learning quality, that is from the result of teaching to search for the measurement and evaluation of physics teaching quality in high school.

2. For the measurement and evaluation of high school physics teaching quality (the way of learning) it gives some thinking and action

From the way of learning, what purpose must the high school shysics teaching quality reach? We think there must be three kinds: grasping the knowledge and method (contains world out look) of physics in high school;

physics ability, essentially the development of ability of doing experiments and thinking (especially creative thinking ability); the formation of good feeling, strong will and nice character (not only belong to non-intellectual factors, but also belong to the formation of the).

How do the students reach these three standards after learning? At present, we can not use one kind of working modes to investigate. Educational evaluation requires to use all techniques to evaluate all the results expected by education. From the necessity of educational modification hoping the measurement and evaluation of our course teaching quality can early go from experience toward the path of scientific direction, teachers and education research people begin to pay attention to the above three purposes. According to their different nature, they use different methods of evaluation: they use standardized test to see the learning results of the students; use ability test to see the development of intellect of the students; use investigation and understanding to see the formation of good feeling, strong will and nice character of the students. Of course, the contents of the three investigations are not mutual exclusive, for example, standardized test of course also requires to test ability; ability test can not leave out knowledge; non-intellectual element also always appears in learning knowledge and intellectual activity. For convenience's sake, we discuss them separately, thus, they themselves separately perform their essential functions.

(1) The measurement of learning result. At present, most schools and teachers still use the method of general examination to measure the physics learning result of the students. The main fault of this kind of examination is that the subject given is not scientific. In different kinds of high school physics examination, except those put emphasis on the contents of examination on the memory of knowledge, and those people neglect the test of ability, more tests are subjective only few are objective. Test problems almost set by few people, sometimes just set by one person's experience, therefore it lacks the theoretial basis of educational measurement, the reliability, validity, difficulty and the discriminating power of the test items are bellow the scientific standard. They are not easy to test the real learning result of physic learning of the students. It is also difficult to distinguish the result of student's learning between different physic teachers in the same school or between physic courses of different schools. In order to test of the learning result at present gradually transformed from experience toward science, the educational department or high schools of some cities, province already try hard to make standardized experiment, gradually build up their own form of physic course. At present, materials of the standardized thests there are very many so there is no need to repeat here.

(2) Exploration of the ability text

Ability, knowledge and technique are closely related to each other But for different from examination of knowledge and technique, we think in the high school physic course, there may be three trials which can put into practice and can get certain results.

i. Test for seeking different ways of thinking General examination also includes intelligence test, the method used is to find out the test of the same thinking. According to this test, one question only gets one answer, requiring people to take tests using the same thinking. It is difficult to avoid students who just depend on memorizing to get high grades, also difficult to avoid hindering the creative ability of the students. In the test to seeking different thinking, there is more than one answer in answer to one question, if the answer is correct, and the more the better, the more special the better. For example, in the physic textbook of junior high school 3rd year about the three applications of convex mirror. According to general examination (require the same as thinking test) we ask what application the convex mirror has. If the students reply three applications written in the book, they can get full grades, but we can not see the difference of intelligence and creative ability between the students. But if we change our question, besides the three applications written of the convex mirror given in the book, what are the other applications? Students get knowledge from different directions, of course if they give more answers (correct) it will be better. There are quite a lot of questions similar to that kind. Of course, all test questions we do not give alike, but by giving this kind of question, we can differentiate the best students and good students.

ii. Test about independent device experiment and practical working. Generally students who take physics examination, also take experiment examination, but they almost repeat the experiments already done, almost just write something on the paper, but never investigate the actual process of work. We may let students independently write something within theteaching outline, but not repeat what is written in the book. For example, in the book for 3rd year junior high school, students already learn about the total resistance of parallel circuits: $\frac{1}{R} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \ldots\ldots\ldots$ This formula comes from the book derived from the knowledge learned by the students. We may let students draw up a plan of experiments to prove the relation-ship: students are given three unknown resistances, one sliping resistance, one ameter, one voltmeter, one key, one low pressure electro-source and several conductors. Require the students to use the apparatus given, create one experiment (draw electric circuit, write a table, give related number and write simple process of proof) to prove this formula, then begin actual work, Generally speaking, in the book, use theory to derive formula, if high school experimental condition permitted, let the students independently set up any experiment to verify. Of course, teaches can let students arrange some other less complicated new experiments.

iii. pre-test

The teachers always investigate the knowledge already learned by the students. Now, so called pre-test is quite different, this is to test students new knowledge (never learned before), thus to investigate the independent ability to get physics knowledge of the students. For example we use first year senior high school physics (A. book) chapter 6, first part, gibe questions of the contents before test, students only learn chapter 5 gravitational law (Students have not learned the contents to be tested, nor are they allowed to prepare beforehand). We introduce what is called balanced condition and give some necessary experimental apparatus, let students themselves discover what is new knowlege for them: "under the action of three forces (from the same point) the balanced condition of the body". We divide this question into 6 parts:

a. Give possible answer (when the body is under the balanced condition, what is the relation existing between three forces at the same point?) students are given 2 minutes to guess.

b. To design an experiment used to explore this problem

    1. draw out experimented diagram.

    2. give a table of experimental number.

c. Tp proceed the experimental drill and take down the experimental data.

d. Use experimental data to draw a diagram, then from the diagram reach the right conclusion.

e. When a body acted by forces from more than three common points, it is on the balanced condition what condition must these forces be satisfied with

f. Can you derive this relationship from what you have learned about the knowledge of physics?

Then, in a school, choose a group of students by giving them examination. First get the original material of each student who takes examination, so that his special ability of thinking can be understood. After analizing these materials, the teachers give comments to each student. For example, from the comprehensive point to see the thinking activity. For the best students, the comprehensive ability is more prominent, in the answer, besides diagram, words are not more than 100, not one single sentence belongs to useless criticizm and the time for the examination is only 16 minutes (generally in class teaching, the teacher usually spends 45 minutes), slow students don't know how to use the resultant force = 0 to express the related conclusion. In the example given above (a body is acted by three forces at common point its condition is balanced) take the answer as an example. One student's answer is: let the level line be the dividing line. The resultant force above the level line and the resultant force under the level line must have equal magnitude and opposite direction, acting one the same straight line; suppose the pulling force on the level line is to use the straight line to divide, resultant force on the left and resultant force on the right to make a pair of balanced force. "From the point of knowledge, we still give full grade; but compared with the student giving answer Resultand force = 0", his comprehensive thinking activity is somewhat lower. This shows these two students from the examination paper get the same grade, but their nature of intelligance is quite different, one student appears to be bright, but the other appears to be not so bright. In different students there always appear different flexibility and independence. Because those important contents of examination have not been learned by the students, they can not depend on remembering, but on self independent thinking to answer these new questions, therefore, it is not only to examine knowledge, but essentially is to use the ability to solve actual problems.

(3) Investigate non-intellectual factors

The history of science shows that non-intellectual factors in the success of educating talents can't be neglected. The good feelings strong will and nice character of the students are also important factors, to measure the teaching quality courses. Of course, the good feelings, strong will and nice character depend on different courses of study and work of all directions to-gether. No doubt, physics course is also responsible for cultivating the excellent feeling, strong will and nice character of students.

Non-intellectual factors always belong to in side of the psychological factor, using pen, paper, grades is hard to correctly evaluate, therefore it is necessary at the same time to do some necessary examination, assisted by extended observation, and going in deep survey. It is not enough to investigate only students, but it also depends on the contact and understanding of the teachers and family heads of the students. They can look for the learning material of the students, know the psychological inclination, then can give comparactively correct education. Now from the paper investigation gives one example. Example: surveying the learning condition of high school physics.

We once in the junior high school physics, give five ways of contents, at the end of every semester, see the degree of interest in learning physics, in the way of learning; investigate how they appear their determination, independence and like what method of teaching and learning.

1. If you compare with other courses, your interest in physics: (1) most interested; (2) comparatively interested; (3) in general; (4) not too interested; (5) not interested at all. Choose one of the five, write in.

2. When you study physics or solve problems, suppose you feel difficult, your habitual way is (1) to ask your teacher; (2) to discuss with your classmate; (3) to investigate and solve the difficulties; yourself; (4) to leave the question, and wait till time of examination, Choose the most often way of doing, fill in the blank.

3. Write down what you have done and learned in this semester; a small creation; write a short essay; participate in physics competition; read outside class physics essay; (already get reward, prize, write down what kind of reward you get.

4. What kind of teacher's teaching you like most? (1) teacher's lecture, students listen; (2) while the teacher talks, explains, he gives out questions (3) teacher gives out questions and let the students discuss; (4) Teachers let students read and learn from reading themselves at first. If they do not understand some passages, teachers will explain. (5) others;

Choose the one you like most and put the number in ( ). If you choose others, write out the essential points of the method.

5. What is your method of learning physics?
Please answer:

(1) Do you have plans of learning? Are you following the time table to learn physics?
.... ( )

(2) Do you have the habit of previewing your lessons?
.... ( )

(3) Do you have the habit to take notes while reading, listening to lectures and reviewing book?
.... ( )

(4) Do you like to do experiments, from doing experiments do you discover new knowledge?
.... ( )

(5) Do you like to ask doubtful questions, but never let the doubtful question pass by while learning
.... ( )

(6) Do you learn physics beforehand? Next semester or still long time afterward lessons?
.... ( )

(7) Do you like to complete your own lessons, but never copy from others?
.... ( )

(8) Do you always take summary of what you learn from physics books?
.... ( )

For the above eight questions, if you can answer certainly, make the sign "x"; if you can't answer, make the sign "?".

Method of explanation: From the above five questions, the 1st and 3rd problems reflect the degree of interest of learning physics by the students; the 2nd and 5th questions reflect the learning inclination of the students; the 4th and 5th reflect the degree of independent learning of the students. Of course, the 3rd and 5th reflect the level, of intelligence of the students too. In point 4 several methods of teaching pointed out is to understand the psychological inclination of the students. Actually, the method of teaching is together up, flexiable, but never use just one of many methods to proceed teaching. Right now, our country proceeds to educational reform, the thought of guidance is to make education fit the requirement of the "three faces". Let students come out from simply searching after the grades of examination, but face the boiling modernized construction. Facing the news flow of the world, facing the 21st century. The measurement and evaluation of course teaching quality must serve the "three faces" teaching reform. Right now we do not completely know the measurement and evaluation of course teaching quality. But, we must stand on our own wide experentce and get help from foreign countries. We believe not too long time, from all directions good thinking and action will be concentrated. Let the measurement and evaluation technique of course teaching quality reach an ideal and perfect condition.

THE IMPACT OF ACOUSTICS TO PHYSICS EDUCATION AND RESEARCH

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Dedicated to Professor Isader Rudnick for his 70th birthday and his distinguished contribution* to physics and acoustics.

Abstract

The classical and highly interdisciplinary nature of the science of sound either occludes its being a branch of modern physics or makes its position in the latter somewhat dubious and mostly unjustified. The purpose of the paper is to explore with illustrative examples that from the unity of physics, the interaction of acoustics with other branch of physics,etc., acoustics, is, as it has always been, an important and indispensable branch of physics though sometimes hidden. The relation between macroscopic acoustics and microscopic physics and other branches of modern physics are discussed in some length. It is a motivative force to the advance of physics for it is very heuristic to some concept and its impact to physics education and research cannot be overemphasised.

I. Introduction

Acoustics, as an old branch of physics, was developed through scientific study of one of the most conspicuous phenomena in our everyday life, and is advancing with all the rest of physical sciences. The negligence of problem as is posed here arised from the fact that acoustics is not omly dated but also a science of more interdisciplinary nature with ever-increasing applications dispersed in engineering and technology, in life sciences and humanity, as shown in appendix I of this paper—a simplification and extension of Lindsay's wheel(1) proposed 21 years ago. The trend of modern physics concern more with the intrinsic of the physical world, with no direct bearings with human senses e.g., the particle physics dealing with the ultimate structrue of matter. Acoustics seems to be off the main stream of modern physics. There are much indications that acoustics does not usually manifest itself as an independent chapter in an undergraduate text of general physics, though a young student of physics may Know the name of Rayleigh from his law of black body radiation or elsewhere rather than from his classical work on theory of sound, from which he actually learns quite a lot. So do some authors(2) in summarizing the progress of modern physics in terms of energy scale. As claimed by P.M. Morse(3) and more recently by R.B. Lindsay(4,5) R.T.Beyer(6), and the present author(7) the extrinsic nature(8) of the science of sound never excludes the importance of its being an important branch of basic physics , and the oversight was examplified(9) by the failure of some brilliant Chinese students with advanced training of theoretical physics to solve a fundamental problem on acoustics (App.II). To the present author, to make this point clear is not as much for those problems or publications already bearing the title of physical acoustics(10), or evidently physics-related, as for those subfields like psycho-acoustics, speech communications, those of more applied nature etc., their direct bearing with modern physics are somewhat vague at first sight. The present author is attempting to clarify that the mutual relations dependence between modern acousticsand modern physics have not been lost in the age of increasing specialization in conformity with the viewpoint as was offered by the aforementioned authors some years ago. This paper will take up the following main themes:

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*Partly introduced by the citation of the Gold Medal awarded to him at the 103rd A.S.A. meeting, Spring 1982(JASA)Supplement 1, vol71,Spring 1982

(i) The parity and disparity of the trend of modern acoustics and that of modern physics;

(ii) acoustics as a branch of modern physics from unity of physics chiefly from the point of view of analogy;

(iii) acoustics as an indispensable part of modern physics. That acoustics has been and will always be one of the motive force for the progress of modern physics and that mutual dependence cannot be overlooked. The impact of acoustics physics education and research cannot be overemphasised.

II. Parity and Disparity of the Trend of Modern Acoustics and that of Modern Physics

Physicists usually consider that the discoveries of cathode rays, radioactivity,etc., not explainable by classical theory, led to the quantum hypothesis by Planck and Einstein, and later the development of quantum mechanics marked a new epoch of modern physics. From then on, the main stream of physics seemed to have shifted to the exploration of microscopic world rather than its classical subjects as acoustics that had once reached its climax. It was really so for the edifice of classical phenominological physics had been considered to be consolidated, finding its ultimate completion at the advent of the theory of relativity. Nevertheless, there were many special problems of hydrodynamics, the diffractions of light and sound,etc. Most of them have developed the theory of holography. As all physicalphenomena are nonlinear with linearity as special cases, problems of nonlinearity have now dispersed in many current fields of sciences including acoustics and particle physics. All these problems once thought not new in their basic framework have had their renewed interests by both physicists and acousticians. For instance the monochromatic coherent sound waves had been discovered long before the advent of laser, however some others are enhanced by the development of quantum mechanics, field theory, etc. and also by the discovery of electrons and other nuclear particles. For instance , the scattering of light and sound (the analogy of which corresponds to the macroscopic relaxational problem of sound absorption in water fogs(32) and their microscopic counterpart(11) i.e., photons, or the scattering of waves and particles(12) cuts across the boundary of classical and modern physics. Specific problems thus from interaction of sound by sound(6,13) to phonon-phonon,electron-phonon and phonon-other "ones",(14) all these belong to problems of fundamental nature, which, of course, involves the study of superconductivity(15) and phonon physics(16). In superfluidity, several sounds other than conventional first sound in ordinary fluids have been found and new modes are developing(18). Strenuous efforts are being made including preliminary report on production of very high frequency coherent phonon beam(19) of the order 10^{12}–10^{13}Hz and for the study(20) of the condensed matter physics. No matter how these achievements are classified, they are at least partly acoustical and those admitted acousticians themselves are of actually participating such development.

The demarcation may seem to arise from some areas of sustaining or even increasing interests of acoustician, but due credits have been shifed to elsewhere but not modern physics. For instance, such pioneer work as was done by W.C.Sabine in architectural acoustics at the beginning of the century has proved invaluable to human culture and yet it had not drawn enough attention to the world of physics for the main trend then was atomic physics. One must not forget that in this branch of acoustics its merits have been shown by some eminent acoustical physicists(6) who had applied quantum mechanical method(21), modern mathematical computer techniques(22) etc.to a better solution of sound waves in enclosed space, in conformity with the criteria determined by subjective judgement. But if a physics teacher takes up such progress as typical example to illustrate the transition of ray theory to wave theory and to relate to modern computer technology, I believe the students will accept it more readily than any other example he has in mind.

Planck once remarked early in this century that one of the essential progresses made in the 20th century was that one could express physical world in quantities instead of qualities through human senses. In acoustics he mentioned expressing pitch on terms of frequencies. Maybe Planck had not given enough consideration of the complexity, if possible, of working out a physical theory for expressing sound quality of a concert hall or anything else of the sort. The hearing mechanisms are lest too intriguing that whemVon Bekesy essentially a physicist, won his Nobel prize his theory of hearing is rather rudimentary indeed. Many capable acousticians have worked for years for the combination of physical theory with engineering practice,and finally many a concert hall with good acoustics is now in existence.Others are working on cochlear mechanics. But either Bekesy's or these ablest acousticians' achievements have been ascribed to elsewhere in spite of the fact that it is essentially physics that leads to such successes. The situation might be quite similar in many other fields of modern acoustics.

So far we may classify modern acoustics into two main categories, one is microscopic and intrinsic which may be more accessible to the trend of modern physics, and the other chiefly macroscopic and extrinsic, which is by no means deviating too far from this trend. In what follows in this paper we shall lay greater emphasis on the second in order to show that both categories obey certain fundamental principles of modern physics.

III. Acoustics as a Branch of Modern Physics from Unity of Physics

In general the development of quantum mechanics is an extension rather than a cut-off from the classical physics. Some branches of classical physics are much related to acoustics, as was declared by Pauli and others. The revolution that brought physics from Newtonian to quantum mechanics, left the thermohydrodynamics unchanged and for this reason the quantum mechanics has been regarded as micromechanics(23). N.Bohr advercated his his corresponding principle with classical physics as the limit of quantum mechanics although his principle must be handled with care. This sort of analogy sometimes engenders new ideas also. Without previous knowledge of acoustical waves, Clerk Maxwell could hardly give the guess that light waves might be just like a sort of mechanical waves in "jelly-like" ether, which finally led to his fomous and elegant theory and equations of electromagnetic field. Appendix III shows the unity of waves equations. Here only linear equations are considered. The detailed derivations can be found in some standard text of mathematical physics. The generalized equation (8) actually laid the basis of field quantization by Heisenberg and Pauli with Appendix IV showing how it was started.

Appendix IV also shows the generality of continuity equation or of mass conservation proposed by De Brogli, which holds true for classical acoustical and electromagnetic waves in connection with quantum mechanics, gravitational waves in connection with general theory of relativity and a number of coupled waves, etc. De Brogli defined density " " and flux " " as the very important properties of all waves. The equation also holds true for particle picture based on his wave-particle dualism.

Appendix V shows the similarity of uncertainty principle in quantum
mechanics and that in acoustics. Heisenberg's uncertainty principle is a
very basic one which states the impossibility of determining the position
and momentum or time and energy of a particle (say, an electron) at the
same time. There are many ways to state such affairs, what we adopt here(24)
is a convenient way by comparing the corresponding well-known problems in
acoustics(25). The comparison shows remarkable resemblance in mathematical
formulation. The acoustical "transients" play an important role both in
speech and music and in vibration, so do the sound recording and reproduction systems. In this connection more extentive works were reported and
confirmed by communication theory(26), and recently by auditory analysis(27).

Appendix VI shows the similarity of tunneling effect of quantum mechanics (such as -emission through a potential barrier, etc.) as was much
discussed in almost every elementary text of quantum mechanics with trans-
mission of plane sound waves through layered media solved by the matrix
method(28) in mathematical expressions of transmissivity.

There are much more examples for illustration. It is very interesting
to mention that P.J.Westervelt(12) had once identified his result obtained
from the intensity of a scattered sound with that of the number of scattered
particles of Rutherford's scattering of -particles with thin foil after
quantum mechanical treatment similar in mathematical expression, and re-
cently more interesting to see that he had correlated his result of tran-
sient performance of parametric sound end-fire arrays with emission of radar
or light pulses emitted from the earth to a planet and thus confirmed the
gravitational waves predicted by Einstein's general theory of relativity.
Puyyerman(29) suggested the ultimate emergence of acoustics and classical
hydrodynamics to modern physics from classical nonlinear theory.

All examples thus mentioned show the unity of physics. Similarity or
analogy in physical concept or in mathematical formulation is by no means
accidental. The analogy usually happens in very remote and unexpected
places.

I should like to mention as one more concrete example to illuminate this argument, i.e., the problem of mutual actions between aerosols in a sound field of practical importance to sonic agglomeration and precipitation already found applications in industry but not so assured to atmospheric science. So far nine different kinds of interactions have been found(30,31), varying in some 17 orders of magnitudes with some attractive some repulsive, some depending on the property of sound fields, etc. Compared with the four interactions of the publicized corresponding problems in particle physics which is of course more intrinsic, it is little known and its progress is very slow. I am sure there will be a breakthrough if more brilliant physicists do not bother to take some time attacking this problem of "classical" nature. An analogy was already shown by the infrasonic absorption of water fogs(32), a purely macroscopic problem, to ultrasonic absorption of molecular level(33,34), both showing relaxational peaks (by considering the fog as an ideal gas with internal degree of freedom) as was confirmed by many authors(App.VII).

IV. Acoustics as an Indispensable Part of Modern Physics

In retrospecting the development of the modern physics one should not forget its historical merit to the advance of concept of optical and electromanetic waves, and hence to that of all waves and wave fields hitherto not fully investigated. One may deny Rayleigh's contribution to Planck's quantum theory but not his contributuion to quantum mechanics, such as partial wave solution for scattering problem, and to Bohr's liquid drop model in nucleal physics, the idea of which might be derived from his early work on surface tension of water(34) in addition to theory of mechanical vibration. Enrico Fermi who was well-versed in hydrodynamics(35) and preferred thinking in terms of concret things(36), started his theoretical derivation of "quantum theory of radiation"(35,1) from the oscillation of a simple pendulm and that of a string as analogy, and elucidating his beautiful theory of beta decay(37) by resorting normal modes of vibrations in enclosed space as an important step. Now acoustics has entered the area of space physics(5).

Since the microscopic part of acoustics belongs to modern physics itself, as already stated in Sec. II, the investigations of physics of fluids and of condensed matter by means of ultrasonics and practersonics would naturally emerge. By combining efforts of physicists and acousticians, high energy coherent phonon beam(39) thereby to obtain the highist lattice frequencies will soon be realized, and then a new epoch will be ushered in with acoustics as an unsurpassed means for the study of atomic forces, electronic structure , and a variety of collective excitations in solids while combining itself with X-ray and neutron diffractions. What we want to bring to notice is that acoustics has been applied frequently by some physicists unconsciously; the development from electron-phonon interaction to a successful BCS theory of superconductivity furnishes one of many examples. In addition, the ultrasonic experiment(40) already predicted a successful verification of this theory.

Let us talk a little more about an old problem of nonlinearity concerning solitary waves now called solitions(41), discovered by Scott Russel from a narrow channel in 1834. It turns out to be a fashionable subject of diversified interests from applied mathematicians to particle theorists in more or less abstract ways. But their existence in acoustics(42) has been shown experimentlly, and the discovery of nonpropagating soliton(43) in small rectangular tray of water by vibrating vertically has brought this phenomenon in nature back to the laboratory and classroom demonstration. We can then study the physics underneath more intuitively. Up to the present, we just can tell how much physics and mathematics and technical applications this unique soliton will involve(44,45,46). Another more important and universal phenomena which are deserving greatest interests to physicists, chemists, mathematicians, biologists and ecologists named "chaos" could be traced back to the time of Faraday and Rayleigh. We now already found out route to chaos can be realized in several acoustic system(47-50).

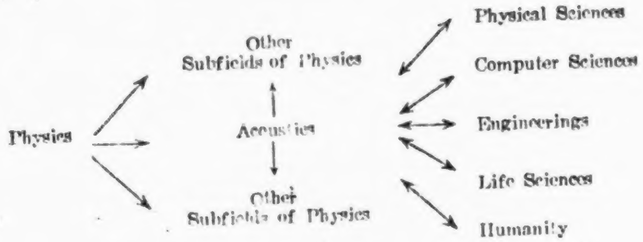
The conbination of acoustics,optics and electronbeam gave birth to the discovery of acoustic microscope,photomicroscope and electron acoustic microscope---these have brought a revolution to conventional microscopy.

V. Conclusion

What has been discussed so far might have shown the close relationship between acoustics and modern physics."Acoustics can't get on very far without the rest of physics and vice versa---the rest of physics can't get very far without acoustics" was what P.M.Morse remarked some 31 years ago. It seems that as diversity goes farther,the demarcation between acoustics and modern physics becomes even vaguer in those overlapped areas where mutual understandings seem to be more pertinent.I should like to quote the paper entitled "Unity of Concept in the Structure of Matter" by John Bardeen,in which he elucidated with convincing illustrations that progress mad in the understanding in one area may often be applied in many other fields.In problems of the structure of matter,he mentioned that the method of elementary excitations should be one of greatgenerality. This certainly holds true in modern physics and acoustics for there are always some linkages between both. In retrospect the author recall he talked the problem of the importance of acoustics in physics with professor L.M.Brebcvskikh,the director of Acoustical Institute of the USSR Academy of Sciences in 1956,and more recently with more American and European physicists and acousticians,they all shared the same viewpoint of mine. From the above mentioned arguements and examples,the author give the name of this lecture as entitled in order to call attention to educators and researchers who think otherwise. As a matter of fact,a concise article but by no means less convincing has already been published.

Appendix

I Extrinsic nature of acoustics.


Physics
Other
Subfields of Physics
Acoustics
Other
Subfields of Physics
Physical Sciences
Computer Sciences
Engineerings
Life Sciences
Humanity

II Unity in wave equation.

L—Lagrangian density, a function of field variable;

$\mathscr{L}$—Lagrangian function;

Q_α—field variables.

Hamilton's principle:

$$\sigma\int_{t_0}^{t}(T-V)dt = \delta\int_{t_0}^{t} L dt = 0 \quad \text{(for any conservative system)}; \tag{1}$$

$$\mathscr{L} = \int L dt; \tag{2}$$

$$L = L\left(Q, \frac{\partial Q_\alpha}{\partial x_j}, \frac{\partial Q_\alpha}{\partial t}, t\right). \tag{3}$$

If x_β is the coordinate of a certain point in the field, we can prove

$$\frac{\partial L}{\partial Q_\alpha} - \sum \frac{\partial}{\partial x_\beta} \frac{\partial L}{\partial\left(\frac{\partial Q_\alpha}{\partial x_\beta}\right)} - \frac{\partial}{\partial t}\frac{\partial L}{\partial\left(\frac{\partial Q_\alpha}{\partial t}\right)} = 0. \tag{4}$$

(4) includes wave equation, heat diffusion equation etc., e. g., let

$$L = \frac{K}{2}\left(\nabla\phi\right)^2 - \frac{\rho}{2}\left(\frac{\partial\phi}{\partial t}\right)^2,$$

and define sound velocity $C = \sqrt{K/\rho}$. then we obtain the wave equation of sound as

$$\nabla^2\phi = \frac{1}{C^2}\frac{\partial^2\phi}{\partial t^2}. \tag{5}$$

Further, let

$$L = \frac{\hbar}{2m}\left[\nabla\phi^*\nabla\phi\right] + \phi^* V\phi + \frac{\hbar}{2i}\left(\phi^*\frac{\partial\phi}{\partial t} - \phi\frac{\partial\phi^*}{\partial t}\right). \tag{5.1}$$

The Schrödinger equation

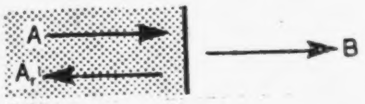
$$\frac{\hbar}{2m}\nabla^2\phi + V\phi = \frac{\hbar}{i}\frac{\partial\phi}{\partial t} \tag{6}$$

can show (4)—the Klein-Gordon equation etc., and
(5)—the Hamilton-Jacobain equation as geometric approximation.

III Simple acoustical problem unsolved by brilliant physics students

On the 1983 CUSPEA exam, students either omitted the unfamiliar problem (for they could choose six problems out of seven or gave wrong answers. The problem runs thus:

Two immiscible fluids are in planar contact as shown below Planar acoustic waves of pressure amplitude A and frequency f are generated in medium (1), directed toward medium (2). Take A and f as given quantities and assume the wave propagation is normal to the interface. Medium (1) has density ρ_1 and sound velocity c_1 while medium (2) has density ρ_2 and sound velocity c_2.



(a) What are the appropriate boundary conditions at the interface?

(b) Apply these boundary conditions to derive the pressure amplitude A_r, of the wave reflected back into the medium (1), and the pressure amplitude B, of thewave transmitted into themedium (2).

This belongs to the simplest case of wave transmission phe nomena, whether the wave is mechanical or electromagnetic in nature. Anyone with a modest training in acoustics could give the right solution right away. One assumes a wave of the form $e^{i(\omega t\mp kx)}$ with the plane of cintact at x=0; the continuity of acoustic pressure at the interface then gives

$$A + A_r = B \tag{7}$$

with $k = 2\pi f/c_1$ and $k = 2\pi f/c_2$; c_1 and c_2 are the phase velocities of sound waves in medium (1) and medium (2), respectively. The continuity of particle velocity (not velocity as given in the official version of the solution that accompanies the problem) yields

$$U_A + U_{A_r} = U_B \tag{8}$$

The specific acoustic impedance is the ratio of sound pressure to particle velocity, or $P/U = \pm\rho c$. The sign is taken as positive for the incident plane wave and for the transmitted wave, which propagates in the same direction; it is negative for the reflected wave. One can thus express the velocity-continuity relation as

$$\frac{A}{\rho_1 c_1} - \frac{A_r}{\rho_1 c_1} = \frac{B}{\rho_2 c_2} \tag{9}$$

Equations 7 and 9 are the required answer in part a. From them, one obtains

$$A_r = A\frac{\rho_2 c_2 - \rho_1 c_1}{\rho_1 c_1 + \rho_2 c_2}$$

$$B = A\frac{2\rho_2 c_2}{\rho_1 c_1 + \rho_2 c_2}$$

which is the answer for part b. No calculus is required.

Since the acoustic impedance that characterizes a given medium in which the sound wave travels is a concept never considered on an equal footing with the refractive index in optics. That may be why the official version of the exam solution answered the second part of the problem by deriving the relation between the sound pressure and particle displacement (actually - is the condensation,usually expressed by s), which only made the calculations much more complicated,and solved part b of the problem in a round-about way.

IV Conservation of particles and ideal fluids.

We also see that if we drop the last term of (4), then it reduces to Lagrangian form of equation of motion for classical field. By assuming the field quantities to be expressed by complex Q_α, and its conjugate Q_α^*, we have

$$\left.\begin{aligned} \frac{\partial L}{\partial Q_\alpha} - \frac{\partial}{\partial x_\beta}\frac{\partial L}{\partial\left(\frac{\partial Q_\alpha}{\partial x_\beta}\right)} &= 0, \\ \frac{\partial L}{\partial Q_\alpha^*} - \frac{\partial}{\partial x_\beta}\frac{\partial L}{\partial\left(\frac{\partial Q_\alpha^*}{\partial x_\beta}\right)} &= 0. \end{aligned}\right\} \tag{10}$$

Pauli introduced the transformation $\phi_\alpha \rightarrow e^{i\alpha}Q_\alpha$, $\phi_\alpha^* \rightarrow e^{-i\alpha}Q_\alpha^*$, ($\alpha$ real and small) or the first guage transformation. By some manipulation, an equation closely connected with conservation of particles was obtained,

$$i\frac{\partial}{\partial x_\beta}\left[\frac{\partial L}{\partial\left(\frac{\partial\phi_\alpha}{\partial x_\beta}\right)}\phi_\alpha - \frac{\partial L}{\partial\left(\frac{\partial\phi_\alpha^*}{\partial x_\beta}\right)}\phi_\alpha^*\right] = 0. \tag{11}$$

De Brogli defined density "ρ" and flux "ρV". All waves obey the continuity equation of "conservation of fluids",

$$\frac{\partial\rho}{\partial t} + \nabla\cdot(\rho V) = 0, \tag{12}$$

which is applicable to both classical and quantum physics, and $\int\rho dt$ is independent of time and equal to 1.

In quantum mechanics:

$$\rho = \phi\phi^* = |\phi|^2. \tag{13}$$

With the Schrödinger equation multiplied by ϕ^* and its conjugate equation by ϕ, we get

$$\frac{\partial}{\partial t}(\psi\psi^*) + \nabla \cdot \left[\frac{\hbar}{2im}(\psi^*\nabla\psi - \psi\nabla\psi^*)\right] = 0, \tag{14}$$

which is another way of expressing I(9), with

$$\rho V = \frac{\hbar}{2im}(\psi^*\nabla\psi - \psi\nabla\psi^*). \tag{15}$$

We can likewise get Eqs. (10), (12) for equations of Klein-Gorden and Dirac. Therefore an analogy exists both in physical concepts and in mathematical formulation.

V Uncertainty principle in quantum mechanics and in acoustics.

In quantum mechanics:

x—position coordinate, $\therefore \quad \bar{x} = \int x|\psi|^2 dx, \quad \psi(x) = \delta(x - x_0);$ (16)

$P = \frac{\hbar}{i}\frac{d}{dx}$ momentum operator; $f(x)$, its eigenfunction; p', eigenvalue

$$\therefore \quad Pf(x) = P'f(x), \quad \because f(x) = e^{\frac{i}{\hbar}p'x}. \tag{17}$$

Let x vary in $\pm a$, i.e., $\delta x = a$, we can prove the probability distribution of P',

$$P' \sim \left[\int_{-a}^{a} e^{-\frac{i}{\hbar}p'x} e^{i\kappa x}dx\right]^2 = \left[\int_{-a}^{a} e^{i\left(\kappa - \frac{p'}{\hbar}\right)x}dx\right]^2$$

$$= \frac{\sin^2\left[(P' - \hbar\kappa)\frac{a}{\hbar}\right]}{(P' - \hbar\kappa)^2}, \tag{18}$$

with maximum at $\hbar k$, and a main peak varies in the interval "$2\pi\hbar/a$", as shown in the figure, i. e.,

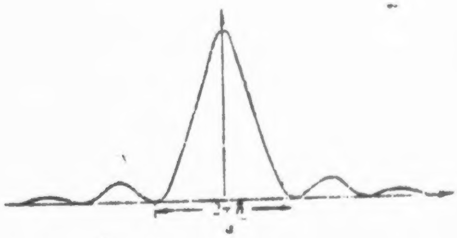
$$\delta p' = \frac{\pi\hbar}{a}, \tag{19}$$

$$(14), (16) \rightarrow \delta p'\delta x \sim \hbar; \tag{20}$$

similarly

$$\delta t \cdot \delta E \sim \hbar, \tag{21}$$

$$E = \hbar\omega, \qquad \delta t \cdot \delta\omega \sim 1. \tag{22}$$



In acoustics:

Let

$$P(t) = \begin{cases} 0 & \left(t < \right. \\ p\cos\omega_0 t & \left(-\frac{\Delta}{2} \qquad \right), \\ 0 & \left(t > \frac{\Delta}{2}\right. \end{cases} \tag{23}$$

By Fourier transform, the amplitude distribution with ω is

$$A(\omega) \sim \frac{1}{\pi} \frac{\sin\left(\frac{\Delta t}{2}(\omega - \omega_0)\right)}{(\omega - \omega_0)},$$

which shows $A(\omega) = 0$ at $\omega = \omega_0 \pm \frac{2n\pi}{\Delta t}$ $(n = \pm 1, \pm 2 \cdots)$. Hence

$$\Delta\omega = \omega - \omega_0 = \frac{2\pi}{\Delta t}. \tag{24}$$

Since only the order of magnitude is considered, therefore,

$$\Delta t \cdot \Delta\omega \sim 1 \tag{25}$$

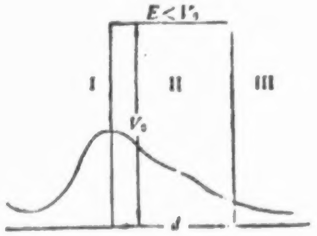
is in agreement with (19) and the sound intensity is

$$I \sim A^2 \sim \frac{\sin^2\left(\frac{\Delta t}{2}(\omega - \omega_0)\right)}{(\omega - \omega_0)^2}, \tag{26}$$

which is similar to (15), all are of the form $\sin^2 x/x^2$.

VI α-emission in quantum mechanics and transmission of sound in layered media or in partitions.

In quantum mechanics:



α-decay,

$$\psi = \alpha e^{ikx} + \beta e^{-ikx},$$

$$\psi_{II} = \kappa e^{\sqrt{\frac{2m}{\hbar}(V_0 - E)}x} + L e^{-\sqrt{\frac{2m}{\hbar}(V_0 - E)}x},$$

$$\psi_{III} = \gamma e^{ikx},$$

where the transmissivity

$$T \sim e^{-2\sqrt{\frac{2m}{\hbar}(V_0 - E)}d} = e^{-2\delta d}. \tag{II 1}$$

The solution depends on $E \gtreqless V$ and the shape of the potential barrier.

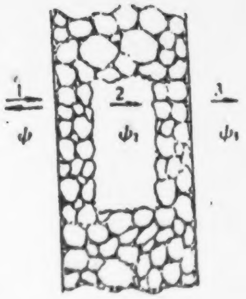
The classical limit, i. e., $\hbar \to 0$, $\mathrm{II}(1) \to 0$.

Solution in quantum mechanics:

$$T = \frac{\text{particle transmitted}}{\text{particles incident}} = \frac{|\psi_{III}|^2}{|\psi|^2} = \frac{4}{4\cosh^2\delta d + (\delta/\kappa - \kappa/\delta)\sinh^2\delta d}. \tag{27}$$

In acoustics:

The corresponding problem is the transmission of plane waves through layered



media, which can be solved easily by matrix method with

$$T = \frac{4r_{13}^2}{(r_{13}+1)^2\cos^2\kappa_2 d + (r_{12}+r_{23})^2\sin^2\kappa_2 d}, \qquad \Pi(3)$$

where $K_2 = \frac{\omega}{c_2}$, r_{13} etc. are impedance ratios,

$$r_{12} = \frac{z_2}{z_1} = \frac{\rho_2 c_2}{\rho_1 c_1},$$

$$r_{13} = \frac{z_3}{z_1} = \frac{\rho_3 c_3}{\rho_1 c_1},$$

$$r_{23} = \frac{z_3}{z_2} = \frac{\rho_3 c_3}{\rho_2 c_2},$$

by assuming that all media are with real z's.

$\because$ $r_{13} = 1$ in II(2), for $z_1 = z_3$; $\delta = i\kappa_2$,

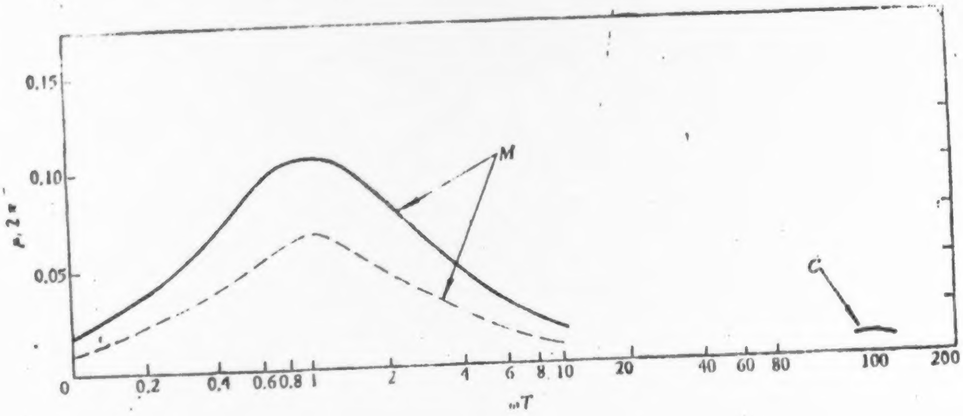
II(2) = II(3) in mathematical form.

VII 1. Infrasonic absorption per wavelength due to mass transfer (denoted by M, solid and dotted curves are results from two different authors; C other mechanisms not considered in this example. See Ref. [36]).

μ—dimensionless absorption coefficient,

ω—circular sonic frequency,

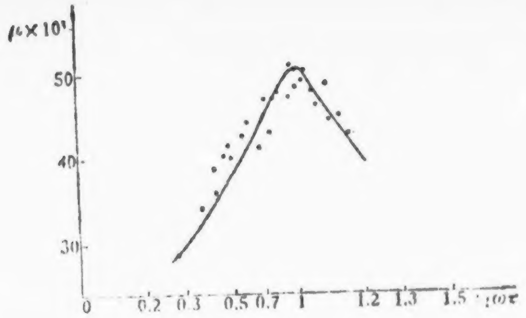
τ—relaxation time, determined by fog constants, etc.



VII 2. Ultrasonic absorption per wavelength arising from rotational isomeric relaxation in ethyl acetate (See Ref. [38]).

ω—sonic frequency,

τ—relaaxtion time.



VIII Acoustic solitons are to be demonstrated by video tapes

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COMMUNITY-BASED PHYSICS TEACHING

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Physics is very much a part of the real, everyday world. It is therefore logical for the physics classroom to open its doors to the immediate outside world which is the community. Community-based physics teaching uses the material and human resources of the community to illustrate physics concepts and address physics-related community needs and problems.

This paper presents a model for community-based teaching and describes an exploratory study undertaken by the Institute for Science and Mathematics Education Development, University of the Philippines.

A Proposed Model

Figure 1 shows a model for the teaching of community-based physics. Three phases are identified and some strategies are suggested for each phase.[1]

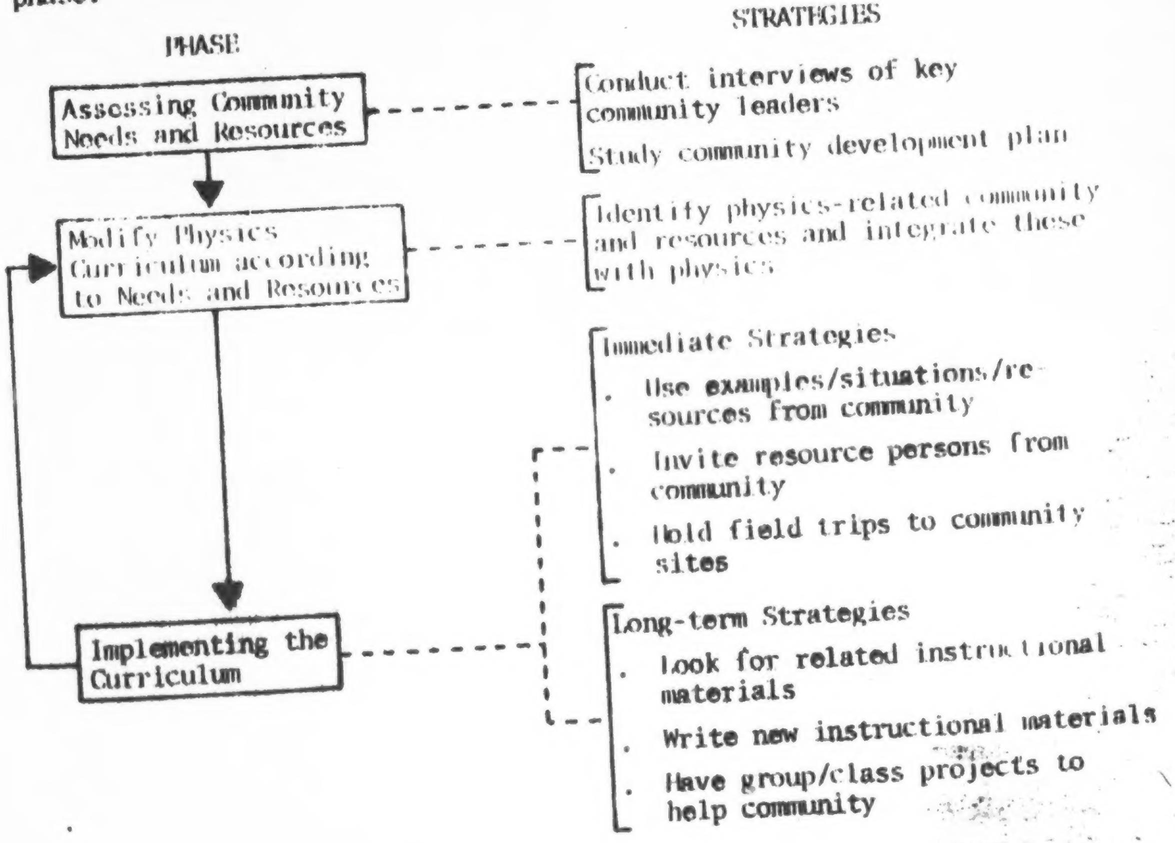
STRATEGIES
PHASE
Assessing Community Needs and Resources
Conduct interviews of key community leaders
Study community development plan
Modify Physics Curriculum according to Needs and Resources
Identify physics-related community and resources and integrate these with physics
Immediate Strategies
. Use examples/situations/resources from community
. Invite resource persons from community
. Hold field trips to community sites
Implementing the Curriculum
Long-term Strategies
. Look for related instructional materials
. Write new instructional materials
. Have group/class projects to help community

Fig. 1. Community-based Physics Teaching

App.1

The first phase, assessment of community needs and resources, is not difficult for teachers who are natives of the locality of the school; they have a fair knowledge of the community needs and resources. For additional information about the community, the teacher or students can interview key community leaders like the barangay captain or town mayor on the goals, problems, resources of the community and how the school can help accomplish certain goals and solve some problems. A community development plan, available in several cities and towns in the Philippines,may replace or supplement the interviews. Such plans typically include characteristics of the community, e.g., topography, climate and population, and development needs and goals for a specified number of years.

During the implementation phase, feedback from students and community folk can be utilized to introduce modifications into the science curriculum for the next cycle of implementation. The cycle is repeated as many times as needed to improve the linkage of the science curriculum with community life. Over the years a reassessment of community needs and resources may be necessary to reflect changes in the community and its development plans.

Rationale of the Approach

Community-oriented teaching provides a rich additional resources base that is within the access of the teacher. Poor schools in particular can draw on community resources to augment their inadequate laboratory facilities and equipment.

Indeed the community environment should be shown to the students as a physics laboratory, too. The relevance of physics will be brought to the fore. This is likely to appeal to the youth who are increasingly becoming socially-oriented. The approach aims to enhance the community awareness and consciousness of the students as well as that of the teacher.

The teacher's perspective of physics in the real world will be widened as he/she establishes linkages with public and private agencies in community development.

If some projects and activities can be designed to help solve physics-related community problems, the students will have made a significant contribution while learning physics. More importantly, they will have had a first-hand experience on the value of physics in community development.

Examples of Projects and Activities

Common community-based activities are field trips to selected sites and talks or interviews of community resource persons. Table 1[2] lists some examples of possible projects/activities based on community need or resource in a farming, fishing, urban or any community in the context of Philippine conditions. Some of these examples were contributed by teachers who were taught in a course or training program by the author.

TABLE 2

Sample Activities/Projects for Community-based High School Physics (Grade 10, Age 16)

Community Need/Resource	Physics Topic	Activity/Project
Farming Community		
Farmer's plow	force, power	Construction of a miniature plow and measurement of its force on different soil types; Measurement of power of a water buffalo pulling the plow and comparison with power of hand tractor.
Farm machines	power, efficiency, energy consumption	Survey of common farm machines in the community and their energy consumption; Comparison of the power and efficiency of selected farm machines.
Adequate land irrigation	relative density	Measurement of moisture content of a soil sample.
Control of crop pests	Bernoulli's Principle	Analysis of the principle of a pesticide sprayer using a half-cut bent straw dipped in water; Calibrating a sprayer to get amount sprayed per unit area.
Rice mill	electric motor, energy conversion	Field trip to a rice mill with advanced discussion on physics questions to ask.
Fishing Community		
Fishing boat	forces, Archimedes' Principle	Construction of a model boat with or without outriggers and analysis of forces involved; Measurement of water line of a boat and factors involved.
Fishing net	stress and strain	Measurement of tensile stress and strain of strings of different materials used for fishing nets.
Fishing canning	pressure, heat and temperature	Observation and analysis of principle of pressure cooker used in canning fish.
Faster fish drying	heat and temperature	Design, construction and use of a solar dryer.
Sea waves	water waves	Observation of wave properties of sea waves.

App.3

Community Need/Resource	Physics Topic	Activity/Project
Urban Community		
Control of traffic	velocity, energy, electric circuit	Determination of rate of flow of vehicles; average velocities; estimation of energy wasted by vehicles in heavy traffic; construction and analysis of a model of traffic lights.
Elevators and escalators	motion, force and electric motor	Investigation of free fall and weight in an elevator; analysis of principle of elevator and escalator in buildings.
Television and radio station	electromagnetic waves, electronics	Visit to a TV and radio station and interview engineer on transmission of elecmagnetic waves; visit to a TV/radio repair shop on physics principles of simple repairs.
Any Community		
Energy sources	energy sources	Survey of energy sources in the community, total energy consumption of community, sectoral consumption; Poster campaign on energy conservation in a community center.
Accurate weighing scales in the market	weight, measurement	Survey of calibrated scales in the market by weighing bought item on the school balance.
Electrification of houses	electric circuits, generation and transmission of electric power	Interview of city/town engineer on the community wiring from the power plant to the houses.
Musical instruments	sound waves	Observation and analysis of how musical instruments found in the community produce sound.
Enlightened public opinion on the Philippine Nuclear Power Plant	nuclear power	Survey of people's knowledge of nuclear power plant; Poster information drive for the layman on facts and concepts of nuclear power.

An Exploratory Study

To try out the community-based model, the Institute of Science and Mathematics Education Development, University of the Philippines, selected three types of community: farming, fishing and urban. The farming and fishing communities selected can be considered rural.

Farming and fishing are the major means of livelihood in rural Philippines. The exploratory study was undertaken in January-March 1985 and August 1985-March 1986.

The Sample. Five high schools were selected based on accessibility and willingness of school officials, one school each in two farming communities, two fishing communities, and one urban community. One physics class (grade 10, age 16) in each school was exposed to the community-based approach; the students totaled 164.

Procedure. The needs and resource assessment was done by students in two schools and by the teacher in one school, through interviews of community leaders. One teacher is a native of the community and another one made use of the development plan of the town.

A total of 12 activities were performed in the five schools with the time spent per activity ranging from one-and-a-half hours to six hours. Activities were mostly done by groups of students.

After each activity, feedback was obtained from the teacher and randomly selected students. They accomplished a questionnaire on (1) whether students enjoyed the activity, (2) difficulties met, if any, (3) physics concepts involved in the activity, (4) whether knowledge of physics is useful for the community, and (5) what students learned from the activity.

Results. Table 2 presents a summary of student feedback on the questions on students' enjoyment of the activities and usefulness of knowledge of physics for the community.

On the students' enjoyment of the activities, the highest response was 'much' for eleven activities and 'very much' for one activity, the interview of fishermen (A_{10}). A few students did not enjoy at all the survey of opinion on the nuclear power plant (A_1) perhaps because of the remoteness of the plant's location. The field trip to a rice mill (A_3) which is next to the school was not much enjoyed by some students. The activity on the measurement of water-level of a low-lying community (A_{11}) which took two weeks was not enjoyed at all by 10% of the students, with another 10% not enjoying much the activity.

On the students' perception of the usefulness of physics for the community, the highest response was 'very much' for all the activities followed by 'much'. In particular, activities found very much useful were the inventory of farm machines (A_{11}) - 100%, interview of engineer on road banking (A_8) - 90%, and interview of fishermen (A_{10}) - 90%. These top-rated activities, however, were all done in one school; the students' motivation for physics in general could be high in this class even without the community activities.

App.5

Table 2. Percent Response of Randomly Selected Students to Community-Based Activity Undertaken by Class

Question \ Activity	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}
1. Was the activity enjoyable?												
Very Much	23	40	10	-	33	44	40	10	40	60	20	20
Much	65	60	70	100	67	56	60	90	60	40	60	80
Not Much	-	-	20	-	-	-	-	-	-	-	10	-
Not at all	12	-	-	-	-	-	-	-	-	-	10	-
2. Is knowledge of physics useful for the community?												
Very Much	63	70	50	57	56	44	80	90	100	90	60	80
Much	12	20	30	43	44	33	20	10	-	10	30	20
Not Much	-	-	-	-	-	23	-	-	-	-	10	-
Not at all	-	-	-	-	-	-	-	-	-	-	-	-
No answer	25	10	20	-	-	-	-	-	-	-	-	-
No. of Students, N	17	10	10	7	9	9	10	10	10	10		10

Description of Activities, A_1 to A_{12}

Parada Barangay High School (Farming Community) : Class Size, $N_C = 54$, February 1985

A_1 = Survey by interview of community folk reactions to ongoing construction of the Philippine Nuclear Power Plant in a distant town.

A_2 = Inspection of transmission lines and transformers in one part of the community.

A_3 = Field trip to a rice mill.

Malolos Marine Fishery School : $N_C = 30$, March 1985

A_4 = Interview of an optometrist and town electric engineer

App.6

Ramon Magsaysay High School (Urban Community) : $N_C = 20$, August-September

A_5 = Survey of accuracy of weighing scales in the market.

A_6 = Observation of traffic flow and determination of speed and acceleration of vehicles.

Philippine National Agricultural School (Farming Community) : $N_C = 17$, September-October 1985

A_7 = Interview of owners of commercial establishments on the implementation of SI units.

A_8 = Interview of a project engineer on the banking of roads.

A_9 = Inventory of farm machines and extent of mechanization of farms.

Malabon Municipal High School (Fishing Community) : $N_C = 43$, November 1985 - January 1986

A_{10} = Interview of fishermen on different types of fishing boat and its parts.

A_{11} = Measurement of water level in flood-prone locality for two weeks.

A_{12} = Survey of energy consumption of households in selected parts of the community.

Some students wrote comments and suggestions. The most common suggestion, given by 13 students, was to continue this kind of activity. No negative comments about community-based activities were given. Perhaps the novelty effect was operating.

The five teachers involved in the study also had a favorable response. Here is a summary of their ratings to the questions on students' enjoyment of the activities and usefulness of knowledge of physics to the community:

Did your students enjoy the activity?

Very Much : A_4
Much : A_1 - A_3, A_5, A_6, A_8 - A_{12}
Not Much : A_7

Is knowledge of physics useful for the community?

Very Much : A_4 - A_6, A_{10} - A_{12}
Much : A_1 - A_3, A_7 - A_9

On the students' enjoyment of the activities, the teacher's perception differed with that of students in three activities; the teacher overrated A_4 and underrated A_7 and A_{10}. On the question of usefulness of physics knowledge, the teacher underrated six activities (A_1 - A_3, A_7 - A_9). On the whole, however, the teacher's perception approximated the students' response.

On the questions on physics concepts involved in the activities and on what was learned from the activities, the students' answers tended to be general perhaps because of the open-ended nature of the questions. Physics topics rather than specific concepts were given. There were a few specific, revealing answers like: I learned why a fishing boat does not sink in water even if the load is heavy. I learned that textile vendors now use metric units.

Problems and Difficulties

Students and teachers involved in the study cited specific problems in connection with the activities undertaken like difficulty in locating the persons to be interviewed, uncooperative or lukewarm respondents, little time given by busy interviewees and communication difficulties with interviewees. The urban students complained of exposure to dust,much sunlight, and onlookers while doing an outdoor activity. One teacher mentioned the little school time available outside the physics class hours for continuing the community-based activity.

Other problems anticipated by science supervisors at the secondary level in the Philippines are: extra time taken up by community-based activities, additional effort of the teacher in making arrangements for the activities, expenses, discipline and safety problems in field trips or outdoor activities, less time for physics in preparation for the national examination and for college work.

Solutions to help solve the problems and lessen the difficulties are also suggested by supervisors and teachers. They argue that if the objectives of the community-based approach are worthwhile, solutions can be found to overcome the problems.

The problems with interviews, for example, can be lessened by prior arrangements by the teacher or students who may know the interviewees, and by training students on interviewing techniques.

The work demand on the teacher and class time requirements can be reduced by assigning the community-based activities to students as group projects to be done outside class hours. In the Philippines, parents' permission will no longer be necessary if activity is done outside school time. Precautions, however, have to be emphasized for students' safety.

Making arrangements and getting the desired cooperation will not be difficult for teachers who grew up in the community of the school. Over the years they are likely to have established linkage with prospective community resource persons. Teachers in the Philippines are generally respected members of the community. In addition people in small rural communities usually know one another.

Community-based activities will necessarily take up class time ordinarily devoted to other physics topics. The physics teacher has to prioritize the topics, sub-topics and activities in the syllabus to delete the less fundamental and important ones, to give way to some community-based activities. The teacher also has to consider the concepts likely to be covered in the national examinations and the concepts preparatory to college physics. The teaching of these concepts can be reinforced with community-based activities.

Physics-related community-based activities are not intended to be done daily or solely in a physics class. The approach is meant to be used whenever possible, together with a variety of teaching strategies at the disposal of the teacher.

Concluding Remarks

The use of community resources and consideration of community developmental needs are also the concern of D. Swift in his book, Physics for Rural Development (1983)[3]. Practical projects for the community like design and construction of solar water heater and wind generator are described in detail in the context of an African village.

Community-based teaching is a major concern of some biologists and biology educators.[4,5] Projects and case studies were undertaken in some countries like Mauritius, Israel and the Philippines. That biology educators have spearheaded community-based teaching is not surprising because of the biological nature of urgent community problems in health, sanitation and population control.

The results of the exploratory study reported in this paper seem to indicate favorable reactions of students and teachers to community-based physics teaching. Further studies using more refined instruments and perhaps an experimental design can investigate effects of the approach on students' attitude towards physics and their mastery of selected physics concepts. Opinions of community leaders and resource persons on the approach can also be obtained.

If the effectiveness of the community-based approach is demonstrated by further studies, the motivation and training of the teacher on the approach is critical in its sucessful implementation beyond the classroom.

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